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Design and Production of an Electrical Resistivimeter

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ABSTRACT: The terrameter is used frequently by geophysics prospecting. It gets two master functions, inject function and the measure function [2] [11]. To improve the working function of this terrameter, we use a laptop with its operating software; it is able to store data, and send them to computer for processing using Bluetooth communication.

The principle is based on the injection of a direct current into the earth through grounded electrodes named A and B [2] [9]. The resulting potential field is measured along the ground using a second pair of electrodes named M and N [2] [9]. Since there is a relation between the apparent resistivity of the subsurface, the injected current and the value of the resulting potential field which allows the apparent resistivity of the soil to be expressed as a function of the DC voltage. After the processing and conversion of the collected data, the software stores the results in a database in order to graphically represent the resistivity as a function of the spatial arrangements of the current injection electrodes (AB/2).

In this study, measurement of the resulting potential field is done by a 24-bit analog-to-digital converter. An 8-bit microcontroller manages the injection of current, the measurement potential field, the conversion and the transfer of data to the PC. Field measurements have been conducted and data were analyzed by correlation calculation as to conclude about the precision of the instrument when taken as reference an existing professional electric system.

KEYWORDS: Resistivimeter, Terrameter, Electrical resistivity, Electrical methods, geophysics prospecting

I. INTRODUCTION

The Laboratory of Geophysical Instrumentation of the Institute and Geophysical Observatory of Antananarivo is operational since January 2003. Its mission is to understand and analyze the functional blocks of the materials used in geophysical prospecting. The electrical geophysical methods are used to determine the electrical resistivity of the earth's subsurface. One of the best instruments is the resistivimeter because of the possible large differences in resistivities in the earth's materials or in underground. Therefore, the

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aim of this study is to present a Resistivity meter used for depth variation of resistivity. It is driven by a computer using serial communication and a microcontroller unit constitutes the heart of the hardware.

II. RELATED WORK

II.1. Electrical method by direct current resistivity

The electrical method is part of active methods. A current I_{AB} is transmitted into the ground with two electrodes (A, B), while the difference of potentials $\Delta V = V_{MN}$ produced by the circulation of this current into the geological layers is measured within two other electrodes (M, N)[9]. The apparent-resistivity ρ of the ground is defined by the relation:

$$\rho = \frac{K * \Delta V}{I_{AB}}$$

, where ΔV is the measured potential difference between M and N, and K is a geometrical coefficient which depends on the separations between the A, B, M, N electrodes:

$$K = \frac{2\pi}{\left(\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}\right)}$$

II.2. The analog to digital converter

We have used the HX711 because of its 24-bit resolution, its support of true differential analog input and its 50Hz/60Hz internal rejection capability if the phenomenon is relatively slow. It operates with the channel A with a gain of 128 and corresponding to a full-scale differential input voltage of $\pm 40mV$, when a 5V supply is connected to the analog power supply pin, AVDD. [8]

The output digits of this ADC are in two's complement format. When input differential signal goes out of the full-scale range, the output data will be saturated at 800000h (min) or 7FFFFFFh (max), until the input signal comes back to the input range.

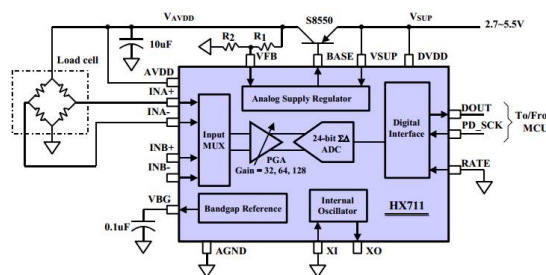


Figure 1: HX711 circuit diagram. It contains the input MUX, the PGA, the 24 bit ADC and digital interface[8]

II.3 The microcontroller

The microcontroller has two functions. The first one is to receive the command from the PC and active a power MOSFET (IRF840) to switch the DC-DC output into the two electrodes A and B (figure 4). Then, the desired voltage is applied between A and B and so to the ground through the contact electrodes-soil. This establishes, some current I_{AB} that is measured at each injection. Each current injection [11] is composed of four stacks: +HV, 0, -HV, 0, where HV is one the high voltage listed above/below. So if the operator wants HV = +200V, we have successively 200V, 0V, -200V, 0V applied as V_{AB} .

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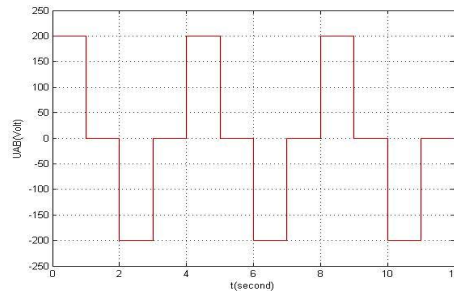


Figure 2: Current injection composed of 4 stacks (200V, 0V, -200V and 0V)

The second one consists of measuring first the potential difference between two others electrodes M and N every 0.8s after each stack, and measured at the same time the current I_{AB} injected. The data obtained are transmitted to the PC for data storage and graphic interpretation.

III. SENSOR BLOCK DIAGRAM

We install a program application in our PC for controlling the resistivimeter (transmitting command to the resistivimeter and receiving data from it). Those commands are composed of: firstly, power the resistivimeter, then choose the voltage output of the DC-DC converter. Possible values are 25V, 100V, 200V or 400V. After that, check the four electrodes by using one electrode, the N one, as a reference, and measure the impedance/resistance between each one of the 3 electrodes and the electrode N [11]. Finally, active the switching power (figure 3).

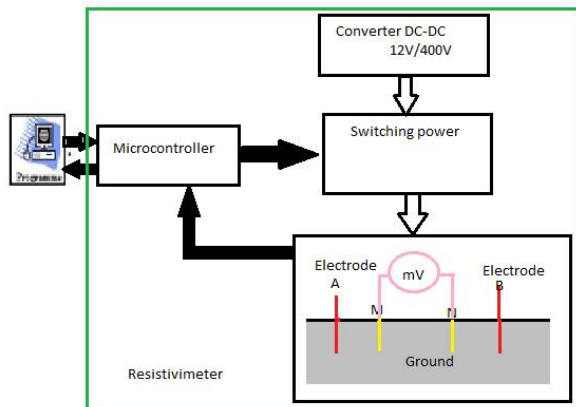


Figure 3: General block diagram of resistivimeter

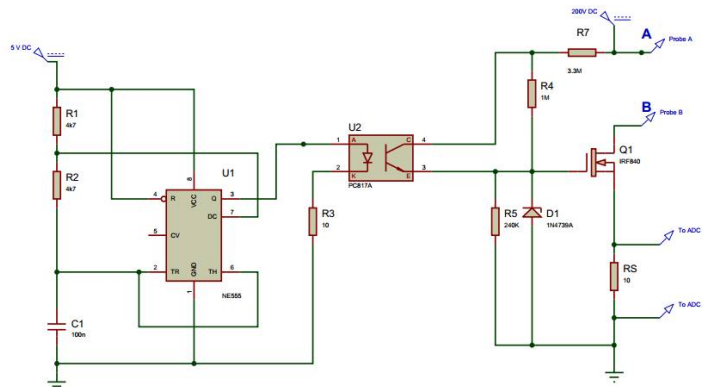


Figure 4: Power generator

Figure 4 shows the power generator, NE555 works as astable operation, PC817 isolates the control part to the power party[3]. The high collector emitter voltage V_{CEO} is 80V[3]. So we choose R7 value 3.3M Ω and R3 value 1M Ω . Knowing R_s voltage, we can determine the current throw A and B.

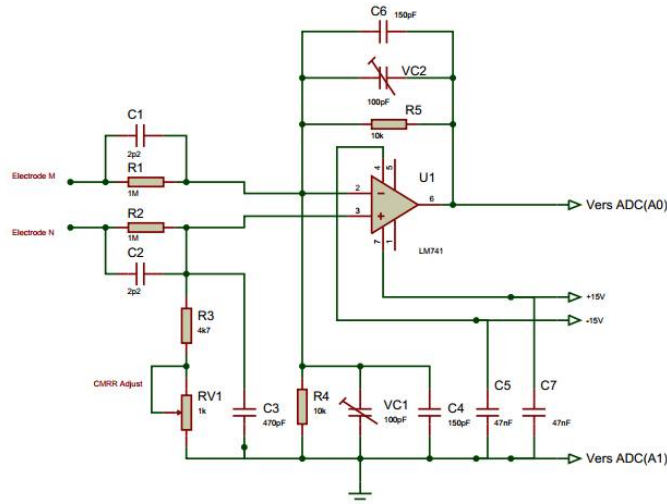


Figure 5: Differential probe between M and N [4]

Simultaneously, we measure the potential difference between M and N (figure 5) using a differential probe. We use an analog digital converter to measure the potential difference between M and N. An accurate differential amplifier is charging to make sure that only the difference potential between the two probes is recorded [4]. This approach also allows the measurement of high voltages without the risk of being confronted with potentially dangerous situations [4]. Knowing that with the type of amplifier operational used here, the gain should only in no case - for reasons of stability - be less than 1, we start by proceeding, through R1 / R4, passive attenuation of a factor 100% of the input signal before giving it, via IC1, a gain of 1 (R5 / R4). The capacitor C8 taken in the line of feedback from IC1 can play on the compensation of our attenuator. The adjustable capacitor C4 has no influence in this context, seen that for this signal the inverting input of the operational amplifier constitutes a point of virtual mass.

IV. EXPERIMENTAL RESULTS

The measurements given by our resistivimeter were compared to data obtained in the same conditions, from the SyscalR2 acquisition chain. We represent in figure 4 the resistivity variation as function of the distance AB/2. On both curves the polynomial approximations (in red) and the experimental results (in green) of the Syscal R2 (figure 4.a) and our resistivimeter (figure 4.b):

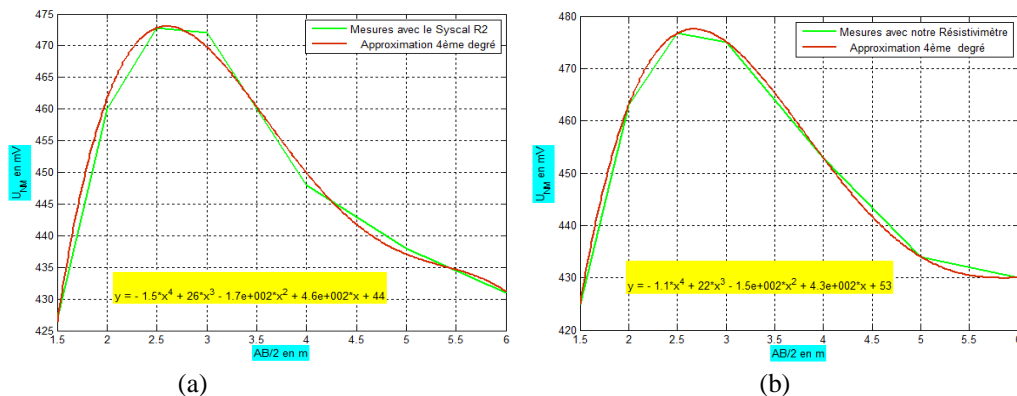


Figure 4: Polynomial approximation and experimental results of the Syscal R2 (a) and our resistivimeter (b). In abscissa, the distance AB/2 in meters and in ordonnee the V_{MN} in millivolts

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Below are the curve fitting results of these data. d is the $AB/2$ distance in meter.

$$U_{MN} = -1.5d^4 + 26.0d^3 - 1700.0d^2 + 4600.0d + 44.0 \text{ (Syscal R2)}$$

$$U_{MN} = -1.1d^4 + 22.0d^3 - 1500.0d^2 + 4300.0d + 53.0 \text{ (Device under test)}$$

The uncertainty of measure between the Syscal data values and our resistivimeter is calculated with the formula [10]:

$$u_c = \sum_{i=1}^n \left(\frac{\partial y}{\partial x_i} \right)^2 u^2(x_i) + 2 \sum_{i=1}^{n-1} \sum_{j=i+1}^n \frac{\partial y}{\partial x_i} \frac{\partial y}{\partial x_j} u(x_i, x_j)$$

Where $u(x_i)$ is the standard uncertainty of x_i , $u(x_i, x_j)$ the covariance between x_i and x_j . In our case, x_i and x_j are the UMN voltage respectively from Syscal R2 and our prototype.

$u(x_i)$ and $u(x_j)$ are the relative uncertainties.

The coefficient correlation between x_i and x_j is given by equation: $r(x_i, x_j) = \frac{u(x_i, x_j)}{u(x_i)u(x_j)}$ [10]

We obtained after calculation $r(x_i, x_j) = 0.9643$.

V. CONCLUSION

- To analyze closely the differences between the two results, we have computed the correlations. This result 0.9643 shows a strong correlation between the two systems.
- Our new resistivimeter is achieving some improvements due to its graphical interpretation simplicity and its capability for deep exploration.
- Our perspectives is to make some investigations on working on more fields measurements to test our new design with various terrains and geological layers as possible. So after, we can have better comparison and appreciations as confronted to literatures as well.

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