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# 2D Multi-Electrode Electrical Resistivity for Horizontal Profiling System

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**Abstract— Electrical resistivity method is one of the most useful technique for groundwater exploration and shallow subsurface studies. Conventional DC resistivity sounding and horizontal profiling method is successful in resistivity survey but is weak in respect of spatial exposure. The 2D multi-electrode resistivity technique is now fairly well established with respect to theory and practical applications.**

**This paper presents laboratory model automatic switching 2D multi-electrode electrical resistivity for horizontal profiling system designed using PIC18F452 Microcontroller, 24bit ADC and analog multiplexers. Analog multiplexers are used for switching the electrodes. This model is designed based on the resistivity principle to acquire the resistivity data for groundwater exploration and shallow sub-surface studies in the lab. Data acquired is sent to the computer through serial port/USB.**

**Index Terms: Automatic Switching, Groundwater, PIC18F452 Microcontroller, Resistivity.**

## I. INTRODUCTION

Resistivity surveys [4] are mostly used for groundwater exploration, shallow subsurface studies, and also for resolving hydro-geological and civil engineering problems [1]. The main intention to design the automatic switching 2D multi-electrode electrical resistivity for horizontal profiling system laboratory model for the students to learn the basics of multi-electrode electrical resistivity survey [5].

Electrical resistivity surveying [2] is also an important geo-physical technique [1] in environmental applications. For example, due to the good electrical conductivity of groundwater the resistivity of a sedimentary rock is much lower when it is water logged than in the dry state. Instead of relying on natural currents, two electrodes are used to supply a controlled electrical current to the ground.

The conductivity of the rock is proportional to the conductivity of the groundwater, which is quite variable because it depends on the concentration and type of dissolved minerals and salts [2] it contains. The large contrast in resistivity between ore bodies and their host rocks is exploited in electrical resistivity prospecting, especially for minerals that occur as good conductors.

As in the telluric method, the lines of current flow adapting to the subsurface resistivity pattern so that the potential difference between Equi-potential surfaces can be measured where they intersect the ground surface, using a second pair of electrodes. A simple direct current can cause charges to accumulate on the potential electrodes [2], which results in spurious signals.

A common practice is to commutate the direct current so that its direction is reversed every few seconds, alternatively a Low-frequency alternating current may be used. In multi-electrode investigations the current electrode-pair and potential electrode-pair are usually interchangeable.

## II. MULTI-ELECTRODE RESISTIVITY PROFILING TECHNIQUE

### A. *Concept of resistivity:*

According to German scientist George Simon Ohm, the electric current [2] **I** in a conducting wire is proportional to the potential difference **V** across it. The relationship is expressed by the equation:

$$V = RI \text{ ---------- } (1)$$

where **R** is the resistance of the conductor. The unit of resistance is the ohm. George Simon Ohm also formulated that resistance in any material is proportional to the length **L** and inversely proportional to the cross sectional area **A** of the conductor [2]. The relationship is expressed as equation:

$$R = \rho * (L/A) \text{ ---------- } (2)$$

The proportionality constant p is the *resistivity* of the material. Resistivity is a physical property of a material [1], which expresses its ability to oppose a flow of charge. Resistivity can be expressed as equation:

$$\rho = (A/L)*(V/I) \text{ ---------- } (3)$$

The resistivity ranges of different rocks and minerals are shown below in **fig 1:**

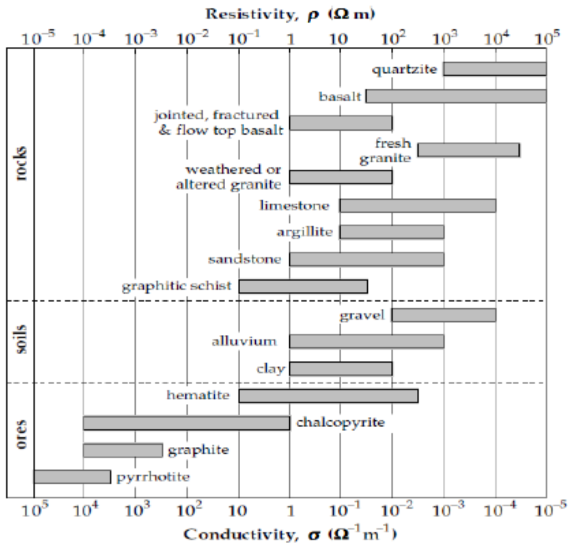


Figure 1: Ranges of Electrical Resistivity for Rocks, Soils & Ores

### B. *Resistivity Surveying:*

Among so many geophysical [1] techniques resistivity method is particularly used for shallow subsurface studies and groundwater exploration [2]. In this method four electrodes are used to measure the resistivity. One pair of electrodes is used to penetrate the current in to the ground and other pair is used to measure the potential difference between the hemispherical [3] Equi-potential surfaces where they intersect the ground surface.

This is the conventional way of measuring the resistivity in



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a uniform half space [4]. The basic arrangement of four electrodes [5] to measure resistivity is shown below in **fig 2:**

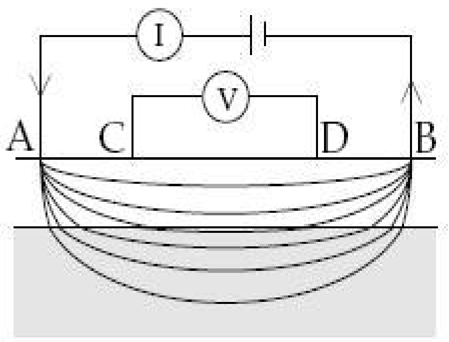


Figure 2: General 4-Electrode Configuration for Resistivity Measurement.

Consisting of a Pair of Current Electrodes (A, B) and a Pair of Potential Electrodes (C, D). There are special configurations to measure the resistivity among them Wenner, Schlumberger and dipole-dipole arrangements are mostly used [3]. In each configuration the four electrodes are collinear but their geometrics and spacings are different. Wenner configuration is used to measure the resistivity in this system [3].

Two modes of investigation can be used in resistivity surveys [4]. They are lateral profiling and vertical electrical sounding. With the lateral profiling survey horizontal variations in resistivity within an area at a particular depth can be determined. Vertical electrical sounding determines the resistivity with depth. Wenner [3] is mostly used in lateral profiling and Schlumberger is used in vertical electrical sounding.

In this configuration the current and potential electrode pairs have a common mid-point [3] and the distances between adjacent electrodes are equal. The basic arrangement of Wenner configuration is shown in **fig 3:**

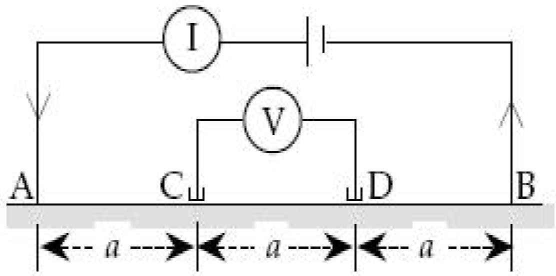


Figure 3: Wenner Configuration Arrangement

In ideal case i.e. in uniform conducting half-space the resistivity determined with four-electrode configuration is the true resistivity but in real situation resistivity is measured by different lithologies and geological structures and so may be inhomogeneous [1].

The resistivity measured assuming the ground is uniform is known as apparent resistivity. In Wenner configuration apparent resistivity is [3] expressed as equation:

$$\rho_a = 2\pi * (V/I) * a \text{ ---------- } (4)$$

This is the formula used to measure the apparent resistivity based on Wenner configuration.

### C. *Multi-electrode configuration:*

In lateral profiling resistivity is measured horizontally. The data points required to measure in profiling is very much larger in count compared to sounding. It is very difficult to measure the large number of data points manually. To overcome this difficulty multi-electrode configuration is used in the resistivity profiling surveys. By increasing the number of electrodes resolution, depth and length can be achieved easily.

By using automatic switching technique four electrodes are selected and apparent resistivity values are measured at specified locations. The arrangement of multi-electrode configuration is shown in **fig 4:**

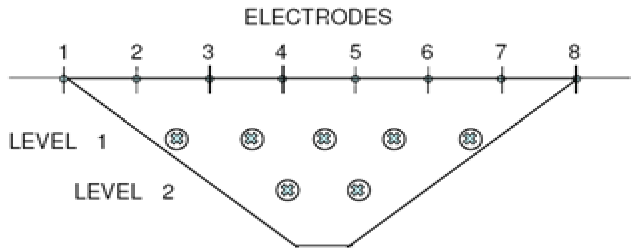


Figure 4: Arrangement of Multi-Electrode Configuration

## III. MULTI-ELECTRODE RESISTIVITY PROFILING SYSTEM DESIGN

### A. *Operation and block Diagram:*

Functional block diagram of automatic switching 2D multi-electrode electrical resistivity for horizontal profiling system is shown in **fig 5:**

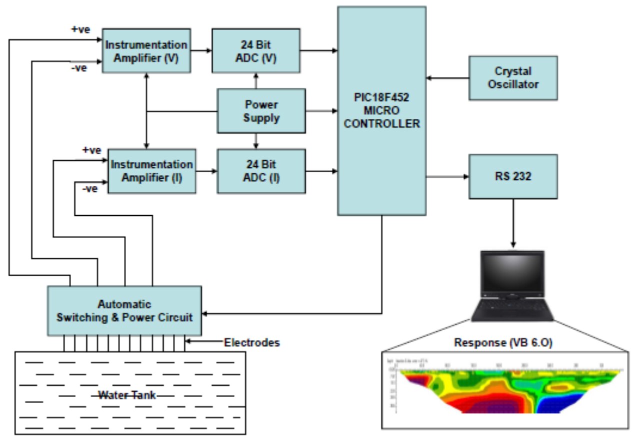


Figure 5: Functional Block Diagram of Automatic Switch Multi-Electrode Electrical Resistivity Profiling System.

PIC18F452 [6] is the controller of the system, which controls all units of the system. Based on the Wenner configuration four electrodes [3] are selected among eight electrodes which are connected to the ground through automatic switching circuit.

The purpose of the switching circuit is to select four electrodes among eight electrodes. Microcontroller controls the selection lines of switching circuit to select the electrodes. After selecting four electrodes power is sent to the ground through current electrodes to measure the resistivity.

Potential difference is measured with potential electrodes and to measure the current, 10 ohm resistor is connected in series to the load. Current is calculated by measuring the voltage across the 10 ohm resistor because the current is same across the load and 10 ohm resistor.



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These two analog voltages i.e. potential difference across potential electrodes and voltage across resistor for calculating current are given to the two different instrumentation amplifiers to amplify the signals. From the instrumentation amplifier, signals are given to the 24 Bit ADC to convert to digital. Microcontroller [7] controls the ADC modules to convert the analog signals to digital and reads data from the ADC modules.

From these data apparent resistivity is calculated based on the Wenner formula [3]. Calculated final apparent resistivity value is sent to the computer through the serial port or universal serial bus. Like this, all the data points are read and sent to the computer. Hyper terminal/Bray terminal is used to display the data on computer. Based on these values further interpretation can be done.

### *B. Hardware:*

Hardware consists of two units: Main board and switch board. Main board circuit diagram is shown in fig 6 and Switch board circuit diagram is shown in fig 7. Main board consists of PIC18F452 Microcontroller [7], ADS1210 ADC, INA101 Instrumentation amplifier and MAX232 RS232 converters as shown in **fig 6:**

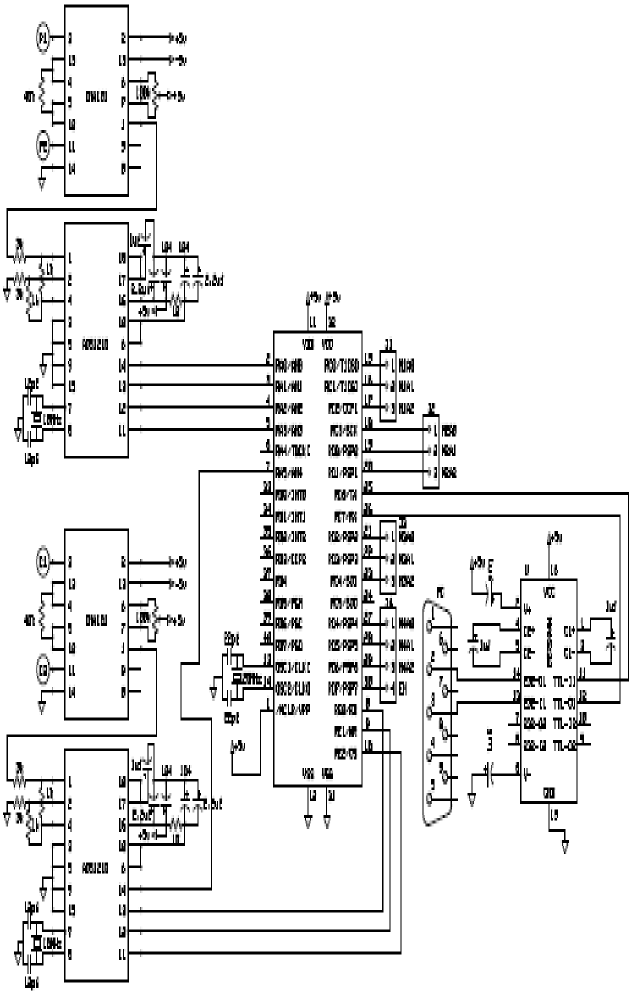

Figure 6: Main Board Circuit Diagram

PIC18F452 [6] is an 8-bit microcontroller from Microchip Company which is used to control the whole system. It runs on +5volts power supply. Maximum Frequency is 40MHz. ADS1210 IC is a 24 Bit ADC used to convert analog signal to digital. INA101 IC is a high gain instrumentation amplifier used to strengthen i.e. to amplify the weak signal.

MAX232 is used for RS232 communication between Microcontroller and Personal computer. Switch board consists of analog multiplexers. HCT4067 analog multiplexers are used for switching the electrodes. These ICs works on +5volts and 16 channel each as shown in **fig 7:**

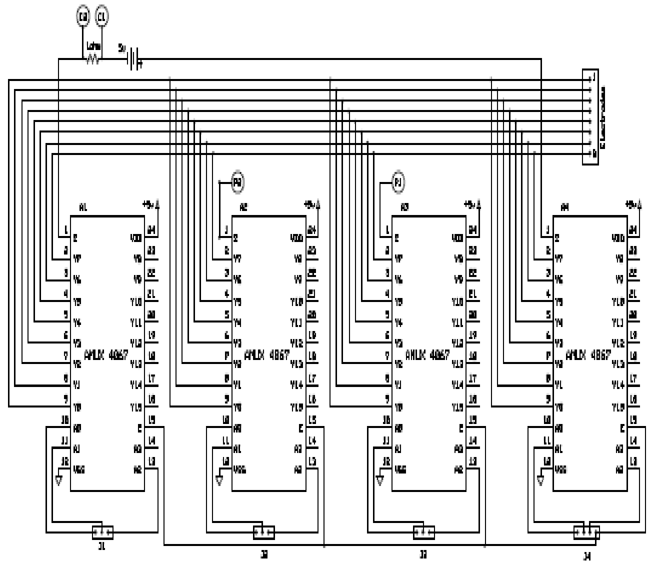

Figure 7: Automatic Switching Board Circuit Diagram

### *C. Software*

PIC18F452 Microcontroller [7] is used to design the system. PIC C Compiler is used for programming. Pic2lite programmer is used for burning the program into the microcontroller.

## IV. RESULTS

Dip the electrodes into the bucket of fresh water and switch on the power supply, and connect to the Terminal v1.9 software. Then resistivity [3] values will be displayed on the screen. After obtaining the values select disconnect option. The resistivity values are as shown in the **fig 8:**

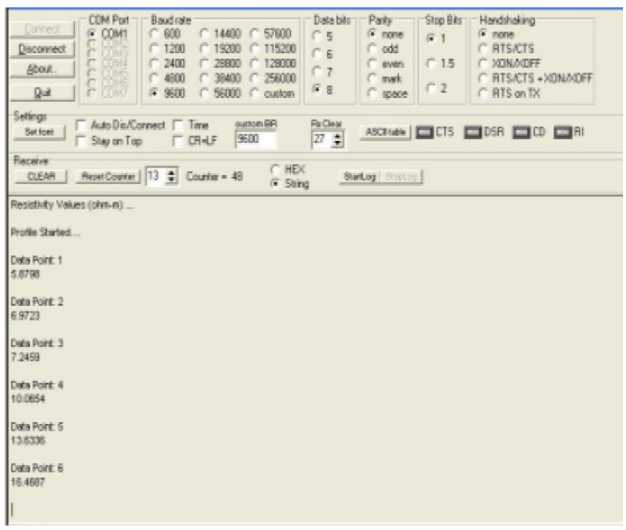


Figure 8: Extracting Resistivity Values

It is known that resistivity value for fresh water is in between 1 ohm-m to 100 ohm-m. Based on the above results it is observed that fresh water is identified.

After acquiring the resistivity values, by entering these values to the visual basic software the color pattern is displayed depending on the resistivity values.



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The difference between Laboratory model and Real-Time model as shown in below table.

Table: Difference Between Laboratory Model and Real-Time model

| S.No | Parameter | Laboratory Model | Real-Time Model |
|---|---|---|---|
| 1 | Performance | Very Good | Good |
| 2 | Cost | Low | High |
| 3 | Time Of Work | Less | More |
| 4 | Circuit Diagram | Easy to Construct | Complex |

## V. CONCLUSION

Automatic switching 2D multi-electrode electrical resistivity for horizontal profiling system laboratory model designed and tested successfully. Eight electrodes are used in this system which can be enhanced further. This low cost system is very much useful for the students to learn the basics of practical multi-electrode electrical resistivity surveys [5] in the laboratory itself.

The applications of Water table depth, Groundwater quality, Geological structure identification and Seawater intrusion etc. The Advantages are less costly than drilling and Non disturbing. The disadvantages are Cultural problems cause interference (example: power lines, pipelines, buried casings, fences) and Resolution.

The future Scope of the Project is based on two dimensions, in future it can be implemented in three dimensions also and more than 12 electrodes increased Resolution. The Limitations of The system is designed only for Laboratory purpose and Resolution can be increased.

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