# A Novel Method of Measuring Soil Moisture

***Shrota Sengupta, Partha Protim Neog, Jyoti Goutam Baruah, Jyoti Barman, Bikramjit Goswami***

**Abstract: This paper is a result of the experimental study of determining soil moisture using a moisture sensor circuit. The technique reviewed here involves the use of a simple oscillator circuit along with a capacitor and application of ANN for automatic detection and optimization. The sensor circuit was calibrated using low and high permittivity material i.e. dry soil and saturated soils respectively. The sensitivity of the circuit was also changed by changing the potentiometer value or capacitance value. The measurements obtained were recorded and used to train the ANN which could then be used to yield the output of the circuit for other input values. This proves to be a novel approach for measuring soil moisture using simple techniques, involving low cost.**

**Keywords: ANN, moisture sensor, Soil moisture, surface soil moisture.**

## I. INTRODUCTION

Soil moisture is difficult to define because it means different things in different disciplines. For example, a farmer's concept of soil moisture is different from that of a water resource manager or a weather forecaster. Generally, however, soil moisture is the water that is held in the spaces between soil particles. Surface soil moisture is the water that is in the upper 10 cm of soil, whereas root zone soil moisture is the water that is available to plants, which is generally considered to be in the upper 200 cm of soil[1].

Compared to other components of the hydrologic cycle, the volume of soil moisture is small; nonetheless, it of fundamental importance to many hydrological, biological and biogeochemical processes. Soil moisture information is valuable to a wide range of government agencies and private companies concerned with weather and climate, runoff potential and flood control, soil erosion and slope failure, reservoir management, geotechnical engineering, and water quality. Soil moisture is a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. As a result, soil moisture plays an important role in the development of weather patterns and the production of precipitation. Simulations with numerical weather prediction models have shown that improved characterization of surface soil moisture, vegetation, and temperature can lead to significant forecast improvements. Soil moisture also strongly affects the amount of precipitation that runs off into nearby streams and rivers. Large-scale dry or wet surface regions have been observed to impart positive feedback on subsequent precipitation patterns, such as in the extreme conditions over the central U.S. during the 1988 drought and the 1993 floods. Soil moisture information can be used for reservoir management, early warning of droughts, irrigation scheduling, and crop yield forecasting.[4]

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## II. THEORETICAL BACKGROUND

Slope failures due to heavy rainfall occur frequently during the rainy season. Such slope failures are mainly caused by increasing soil mass and decreasing shear strength in the soil as a result of increased water content or groundwater levels. Thus, in addition to measuring the rainfall intensity on the ground surface, measuring the water content underground is also important to predict the possibility of slope failures due to rainfall. Conventional field-monitoring systems usually use a tensiometer or a permittivity soil moisture sensor to monitor the soil's moisture[7].

Moisture may also limit microbial activity in a wide range of environments including salt water, food, wood, biofilms, and soils. Low water availability can inhibit microbial activity by lowering intracellular water potential and thus reducing hydration and activity of enzymes. In solid matrices, low water content may also reduce microbial activity by restricting substrate supply. As pores within solid matrices drain and water films coating surfaces become thinner, diffusion path lengths become more tortuous, and the rate of substrate diffusion to microbial cells declines[8].

Soil Moisture Measurement has a few other applications:

- Irrigation and sprinkler systems.
- Moisture monitoring of bulk foods.
- Rain and weather monitoring.
- Environmental monitoring.
- Water conservation applications.
- Fluid level measurements[2].

The technique used in our experiment is illustrated by the following block diagram, shown in figure1.

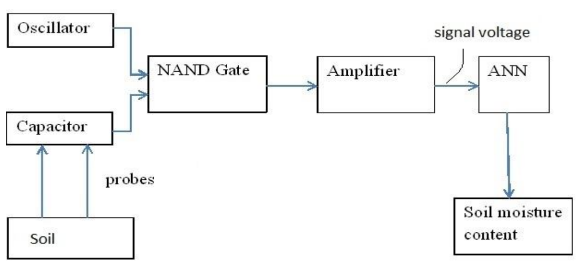


Figure1: Block diagram of soil moisture sensing technique

Here the input from the oscillator and probes via capacitor are fed to the NAND gate which is then given to the amplifier. When the soil moisture is low, the input from the oscillator cannot be diverted to the ground by the capacitor, but is rather fed to the NAND gate. However when moisture content is high, the supply is diverted to the ground. The amplifier further sends the amplified voltage signal to the ANN which then gives the final moisture content.

The circuit diagram used is shown below in figure2.

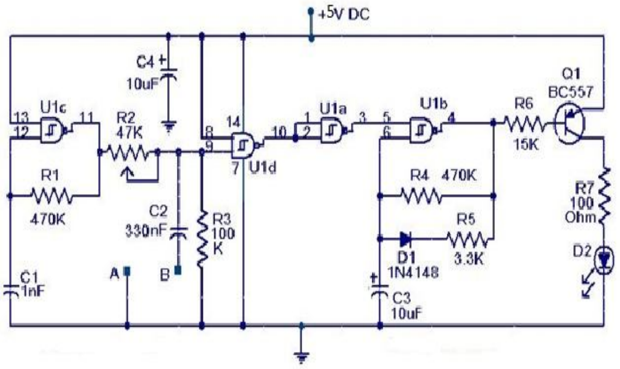


Figure2. Moisture Sensor Circuit.

## III. CIRCUIT DESCRIPTION AND PROCEDURE

The U1C(NAND gate) and associated components are wired as an oscillator producing a 2KHz square wave. This square wave is given to one gate input of U1D via a variable potential divider former by R1 and R2.When the resistance across the probes A and B are low that is when soil moisture level is high, the C2 will divert the square wave to ground. The output of U1D will be high. The U1 A inverts this high state to low and so the IC U1B is blocked from producing oscillations. The LED will remain OFF. When there is no moisture across the probes, the C2 cannot bypass the 2KHz signal to the ground and it appears at the gate input of U1D.The output of U1D goes low, and it is inverted to high by U1A.The oscillator wired around U1B is activated and it starts oscillating. These oscillations are amplified by Q1 to drive the LED and LED starts pulsating as an indication of low moisture. Since square wave is used there won't be any oxidation on the probes. The resistor R7 limits the current through LED and ensures a longer battery life.

In order to calibrate the sensor circuit, a few experiments were performed with different sensitivities. The sensitivity of the circuit was varied by changing the values of its potentiometer or capacitor.

The experiment was conducted as follows:

a. A pot was filled with 5kg of completely dry garden soil.
b. The potentiometer of the circuit was set at different values and a supply voltage was given to the circuit.
c. The probes of a CRO were connected across the capacitor $C_2$.
d. The input probes of the circuit were then inserted in the soil pot and the voltage reading was taken from the CRO.
e. Water of a measured quantity was then added to the pot, mixed well (so as to have uniform moisture) and step(d) was repeated.
f. Steps(e) and (d) were repeated with different quantities of water.

The sensitivity of the set-up was found to be satisfactory after the tests.

## IV. RESULTS AND DISCUSSIONS

Experiments were performed on the moisture sensing set-up shown in figure2 with a supply voltage of 4.5V. the resistor(pot) $R_2$ was set at 34kΩ. When the input probes were kept in air, the voltage across the capacitor was found to be 3.4V. Further the probes were inserted in dry soil. Then measured quantities of water were added to the soil, ranging from (0-84)mL/kg and the corresponding readings were noted as shown below in table1.

Table1

| Water(ml/kg) | Output(V) |
|---|---|
| 0(air) | 3.4 |
| 0(soil) | 3.2 |
| 1.5 | 3 |
| 6 | 2.8 |
| 12 | 2.6 |
| 18 | 2.3 |
| 24 | 1.8 |
| 30 | 1.6 |
| 36 | 1.1 |
| 42 | 0.9 |
| 54 | 0.8 |
| 66 | 0.5 |
| 78 | 0.2 |
| 84 | 0 |

With the data shown in table1 a curve was obtained for soil moisture versus output voltage.

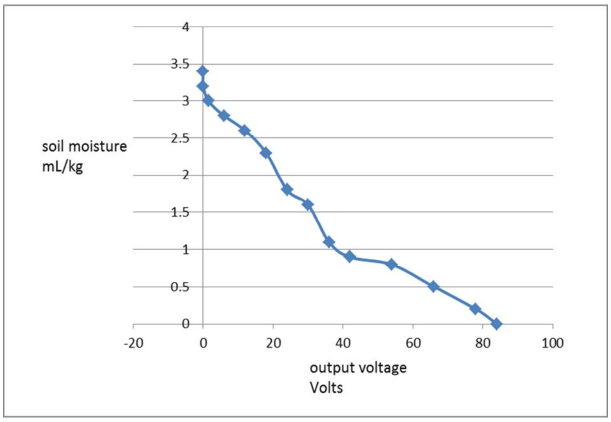


Figure3. Soil moisture versus output voltage plot.

The plot shows an exponential curve which can be defined by the equation(1) shown below.

$$y = -0.0391x + 2.9902 \quad \ldots\ldots(1)$$

Again, with the set-up shown in figure2 another experiment was conducted but with the following modifications:

- Supply voltage=5V
- Resistor(pot)$R_2$=24kΩ.

Likewise, the probes were inserted in soil and measured quantities of water, ranging from (0-65.7)mL/kg were added to it and the corresponding readings noted as shown below in table2.

Table2

| Water(ml/kg) | Output(V) |
|---|---|
| 0 | 4 |
| 4.2 | 3.5 |
| 8.57 | 3 |
| 12.85 | 2.6 |
| 18.57 | 2.2 |
| 27.14 | 1.5 |
| 35.7 | 1.1 |
| 44.29 | 0.7 |
| 52.86 | 0.4 |
| 61.43 | 0.2 |
| 65.7 | 0 |

With the data shown in table2 a curve was obtained for soil moisture versus output voltage.

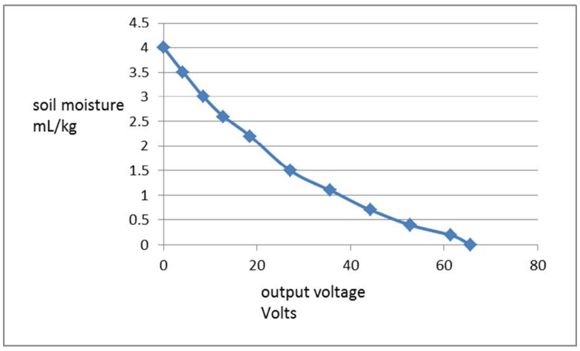


Figure4. Soil moisture versus output voltage plot.

The plot shows an exponential curve which can be defined by the equation(2) shown below.

$$y = -0.0583x + 3.5001 \quad .......(2)$$

Again, with the set-up shown in figure2 another experiment was conducted but with the following modifications:

- Resistor(pot)$R_2$=35kΩ
- Capacitor($C_2$)=183nF(approx)

The probes were inserted in soil and measured quantities of water, ranging from (0-64.29)mL/kg were added to it and the corresponding readings noted as shown below in table3.

Table3

| Water(ml/kg) | Output(V) |
|---|---|
| 0 | 4 |
| 8.57 | 3 |
| 17.14 | 2.8 |
| 25.7 | 2.2 |
| 34.26 | 1.2 |
| 42.86 | 0.8 |
| 51.43 | 0.4 |
| 60 | 0.15 |
| 64.29 | 0 |

With the data shown in table3 a curve was obtained for soil moisture versus output voltage.

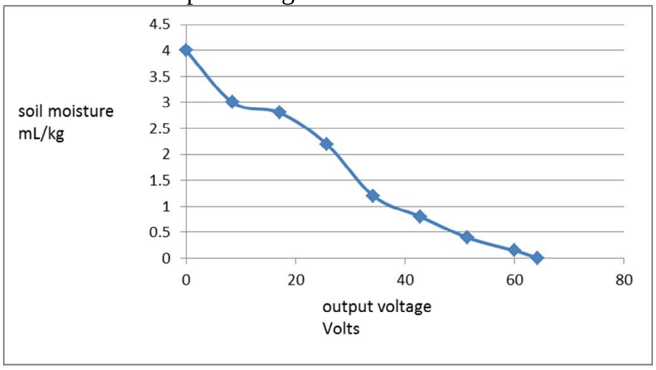


Figure5. Soil moisture versus output voltage plot.

The plot show exponential curve which can be defined by the equation(3) shown below.

$$y = -0.0621x + 3.7168 \quad ........(3)$$

The voltage output shows the corresponding change in voltage for change in the moisture content of the soil. The more is the moisture level, the lesser the voltage across the capacitor.

The values of the above experiments were fed to the ANN program to train it. Hence the output of the intermediate values could be found out using the program. A few such outputs are shown below:

i. for Voltage=1.3V
   water content=211.29mL/kg

ii. for Voltage=2.5V
   water content=70.74mL/kg

## V. Conclusion

The results found in the above experiments could be used in calibrating voltmeters to give the soil moisture content.

This study can be very useful in the following aspects:

- Determine need for irrigation.
- Determine growing conditions for trees, turf and plants anywhere.
- Determine soil moisture percentage for geotechnical and civil engineering purposes[2].

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## REFERENCES

[1] Karim, Bin Ismail,"Soil moisture detection using Electrical Capacitance Tomography (ECT) sensor."

[2] "Soil Moisture Measurements",www.eijkelkamp.com.

[3] Collins, J.E. 1987. Soil moisture regimes of rangelands: using datapods to record soil moisture. International Conference on Measurement of Soil and Plant Water Status. Centennial of Utah State University.

[4] Stafford, J.V. 1988. Remote, non-contact and in-situ measurement of soil moisture content: a review. J. Ag. Eng. Res.

[5] Price, R.R., Ximing Huang and L.D. Gaultney. 1990. Development of a soil moisture sensor. Paper No. 90-3555, ASAE, St. Joseph, MI 49058.

[6] Katsuhiko Tanaka, Makoto Shimamura, Asako Togari, Takefumi Suda, Kazuhiro Hirai,Kazunari Sako, Ryoichi Fuakgawa Ritsumeikan University Kusatsu, Japan," Monitoring of Soil Moisture and Groundwater Levels Using Ultrasonic Waves to Predict Slope Failures".

[7] John M. Stark1 and Mary K. Firestone,"Mechanisms for soil moisture effects on activity of nitrifying bacteria", Applied and Environmental Microbiology, Jan. 1995, P. 218–221

[8] K. Tanaka, T. Suda, K. Hirai, K. Sako, and R. Fukagawa,"Monitoring of Soil Moisture and Groundwater Level Using Ultrasonic Waves to Predict Slope Failures," Japan. J. Appl. Phys. (in Press).

[9] S. O. Kasap, D. Lakhanpal, C. Patzer, T. Mandziak, and D. G. Fredlund, Ultrasonics, Vol. 32, 379, 1994.

[10] Y. Taneda, M. Tomita, A. Kawabata, and T. Shiozaki: Transactions of the Japanese Society of Irrigation, Drainage and Reclamation Engineering (Nogyo Doboku Gakkaishi), 46, 1974 (in Japanese).

[11] T. Suzuki, S. Kagawa, and T. Uchimura, "Investigation of moisture contents in slope ground by change in wave velocity," Proc. the 43th

[12] Conf. on Geotechnical Engineering, 2008, 972, 1943 (in Japanese).

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