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A DIGITAL SOIL MOISTURE METER USING THE 555 TIMER

Sam B. Onoja[1], Jonathan A. Enokela[2] and Grace O. Ebute[1]
[1]Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Nigeria
[2]Department of Electrical and Electronics Engineering, University of Agriculture, Makurdi, Nigeria
E-Mail: jonajapeno@gmail.com

ABSTRACT

A soil moisture meter is useful for the indication of the amount of water content of a given soil sample. This information is especially useful to people involved in the management of irrigation systems and to other professionals who need to measure soil water contents. This project focuses on the design and implementation of a digital soil moisture meter that uses the 555 integrated circuit timer as a major component of the design. The 555 timer was configured so that the probes connected to the soil indicate the resistance of the soil under test and hence the water content of the soil. The digital soil moisture meter was calibrated and the reading, which is displayed on a liquid crystal display panel, ranges from 0.01 to 9.96 ohms-centimeters for very dry soil to very wet soil. The blinking of a bank of light-emitting diodes connected to the meter visually indicates the moisture content of the soil being sampled. The meter was constructed and packaged so that it is very portable and can be used by farmers and other professionals on the field.

Keywords: soil, moisture, irrigation, IC timer.

INTRODUCTION

Crop production requires water at different stages of production from generation through to harvest and also at different amounts. This water is stored in the soil where the crop is planted. The water may come from rainfall or from irrigation. Where water is by irrigation, it is important to measure soil moisture from time to time to be able to know the soil moisture status and determine the amount of water to apply. As irrigation based farming developed, water management became important, stressing the need to measure soil water content and the use of water by plants [1, 2, 3, 4].

Nyle *et al*., [5] described soil as comprising four components namely gas phase (soil air), liquid phase (soil water), solid phase (mineral matter), and organic matter. Soil water (moisture) is held in the soil as a result of forces which invariably control their availability to plants and also control infiltration and soil moisture tension. The availability of water for plants can be enhanced if adequate moisture is stored at the root of plants.

The different techniques and methods that have been developed to measure soil moisture include hand-feel and appearance method, gravimetric and volumetric direct measurement method, dielectric constant soil moisture probe and meter, neutron probe moisture meter, gypsum-porous blocks/electrical resistance sensors, tensiometers, capacitance sensing, Trime FM3 moisture meter and T3 Access tube probe, CS616 (CS615) water content reflectometer, and digital soil moisture meter, among others [6, 7]. Soil moisture meters have been used for monitoring the soil moisture content in irrigation farms. It is also important in the scheduling of irrigation and estimating the amount of water to apply in irrigation. In the estimation of evapotranspiration and proper interpretation of soil-plant relationship, there are complex moisture meters (sensors) used by agriculture and gardening professionals as part of a larger weather monitoring of irrigation systems. Such moisture meters are generally used to record soil moisture along with a collection of other weather related data [8, 9, 10].

The digital soil moisture meter (DSMM) is an electronic device which measures soil moisture content accurately and precisely. It is simple, compact, portable and auto ranging i.e. the internal circuitry selects the proper range for the meter. Values are processed by digital circuits and are displayed on a liquid crystal display (LCD) with decimal values displayed automatically [11]. A relationship between electrical parameters and soil property (SP) such as water content, bulk density, or salt content may be expressed as in equation (1):

$$SP = a_1 \exp(-b_1\varphi) = a_2 \exp(-b_2 E_R) \qquad (1)$$

In equation (1) a_1, a_2, b_1, and b_2 are empirical parameters; φ is the electrical potential, and E_R is the bulk electrical resistivity of the soil. Some other specific relationships between soil property and water contents are reported in the literature [12]. The relationships are generally not linear [13].

In this work a digital soil moisture meter is built around the 555 integrated circuit [14, 15]. The working principle of the meter is similar to that of other digital soil moisture meters that use resistance sensing, capacitance sensing, (CS616, CS615), and water content reflectometer. The meter measures resistance to flow of electric current between two metallic probes. These probes act as sensor elements which register the moisture and change it into an electric value. This electric value is further processed into information in form of electronic display. The materials used in the design of the meter are easily available.

CIRCUIT DESIGN AND CONSTRUCTION

The circuit diagram of the digital soil moisture meter is shown in Figure-1. The 555 timer is operated in the astable mode. The circuit is powered by a 9-Volt battery. The frequency f at which the circuit operates is

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related to the other components of the circuit as given in equation (2) [16]:

$$f = \frac{1}{0.693(R_1 + 2R_p)C_1} \qquad (2)$$

In equation (2) R_p is the resistance of the soil measured between the probes.

The probes of the meter are inserted into the soil to determine the moisture content. Due to the conductivity of the soil the insertion of the probes causes the timer to oscillate at a frequency that is proportional to the available moisture content of the soil. This oscillation is visually indicated by the light-emitting diodes (LED) that are connected to the output of the timer. The LEDs flash faster when the soil contains more moisture. The output signal from the timer is also displayed on a liquid Crystal Display (LCD) panel. The indication on the LCD gives the bulk resistivity of the soil between the probes in Ohms-centimetres. For each measurement, the probes are inserted into the soil at a constant distance between them. The circuit of the digital soil moisture meter was built and packaged as shown in the photograph of Figure-2.

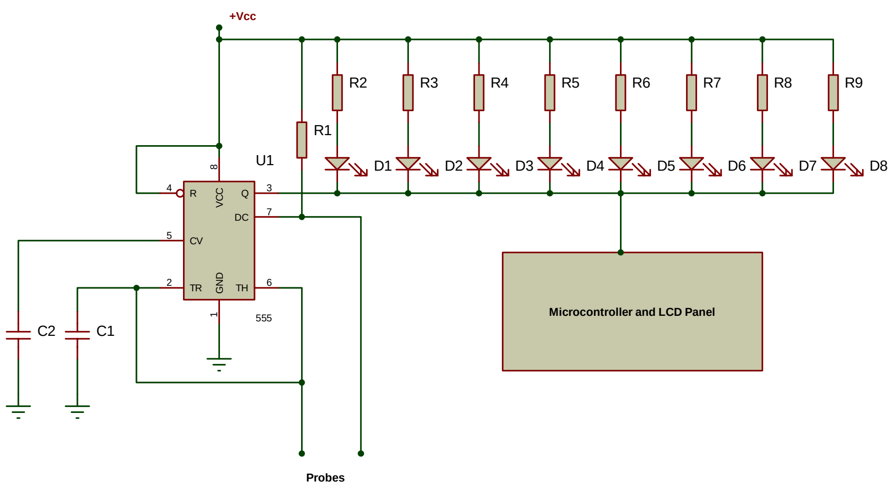

Figure-1. Schematic diagram of the digital soil moisture meter.

Figure-2. The assembled digital soil moisture meter.

Calibration of the digital soil moisture meter

Twenty soil samples were collected randomly from soil conditions ranging from very dry to very wet depicting different moisture contents. The soil samples were collected using moisture cans. The weights of the moisture cans were measured and thereafter the soil samples were put into the cans and weighed. The DSMM was used to take the readings of moisture content of the soil samples. The samples were oven dried at 105 ^{0}C for 24 hours and reweighed to determine the percentage moisture content in accordance with equation (3). The measurements were made in the laboratory and the results are shown in Table-1. The data were used to calibrate the DSSM and the calibration curve, which shows the percentage moisture content versus the reading of the DSMM in Ohms-centimetres, is depicted in Figure-3.

$$P_{mc} = \frac{W_{ms} - W_{os}}{W_{ms}} \times 100\% \qquad (3)$$

In equation (3) P_{mc} is the percentage moisture content of soil sample, W_{ms} is the weight of moist soil sample and W_{os} is the weight of oven-dry soil sample.

In order to validate the laboratory measurements the DSMM was taken to the field and used to measure soil moisture contents with the aid of the calibration curve earlier obtained. The field measurements were made at random places after which soil samples at the points where the readings were taken were collected and taken to the laboratory for oven drying and weighing to determine the moisture contents of these samples. The comparison of results obtained from these measurements is given in Table-2.

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Table-1. Digital soil moisture meter readings and Percentage moisture contents of soil samples obtained from oven drying process.

Sample	Moisture content (%)	DSMM readings (Ω-cm)
1	0.00	0.00
2	11.01	1.72
3	14.96	2.23
4	16.66	2.53
5	18.46	2.79
6	23.52	3.40
7	24.30	3.50
8	36.76	4.05
9	40.51	5.00
10	40.84	5.14
11	41.34	6.43
12	42.38	6.50
13	44.30	6.73
14	49.35	7.60
15	54.99	7.86
16	64.17	8.68
17	71.54	8.97
18	90.25	9.55
19	91.15	9.86
20	92.69	9.96

Table-2. Comparison of soil sample moisture readings using digital soil moisture meter calibration curve and oven drying process.

Samples	Ohms –cm	Moisture content % from oven-drying	Moisture content from calibration curve	Difference	% Difference
1	2.50	16.50	16.00	0.50	3.00
2	3.08	21.00	20.50	0.50	2.38
3	5.01	40.66	40.00	0.66	1.62
4	8.66	64.14	63.00	1.14	1.77
5	8.68	64.17	63.20	0.97	1.51
6	2.40	15.00	14.93	0.07	0.47
7	3.78	26.38	26.00	0.38	1.44
8	3.97	27.26	27.00	0.26	0.95
9	8.98	66.13	66.00	0.13	0.20

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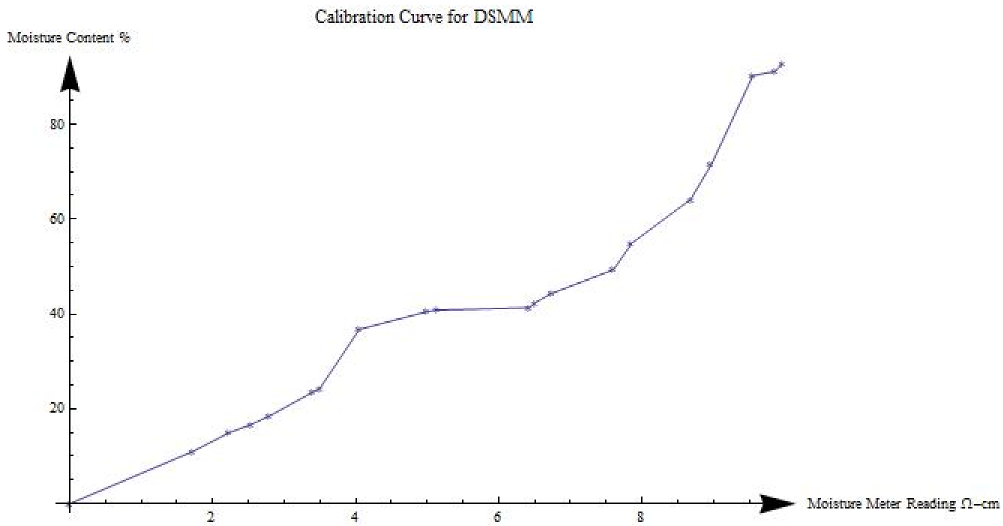

Figure-3. Calibration Curve for Digital Soil Moisture Meter.

Performance evaluation of the digital soil moisture meter

When the LEDs blink and the meter also displays values at different intervals it shows that the soil has moisture. When the soil contains more moisture the LEDs blink faster and the meter indicates a value on the LCD panel. When the moisture content of the soil is low the blinking reduces. This implies that the more the moisture contents of the soil the faster the blinking of the LEDs and vice versa. It was observed that when the digital soil moisture meter was powered, the LEDs were lit and a residual value of 0.01 Ω-cm was read before the probes were inserted into the soil. When the probes were inserted into the soil the meter read values from 0.01 Ω-cm to 9.96 Ω-cm depending on the soil moisture content. The DSMM basically measures the bulk resistivity of the soil between the probes. The probes were kept at a distance of few centimetres apart so that the measurements are translated into Ohms-centimetres.

The difference in the measurements of moisture contents obtained through the gravimetric method and the results from the calibration curve of the DSMM ranged from 0.2% to 3.00% with a mean deviation of 0.512 %. This difference could be attributed to:

a) The calibration curve did not pass through the origin for percentage moisture content and Ω-cm axes, because we did not really have a zero value for the DSMM readings.
b) The depths of penetration of the probes into the soil and soil samples affect the bulk resistivity.

CONCLUSIONS AND RECOMMENDATION

A simple digital soil moisture meter using the 555 timer as the major electronic component has been designed and built. The digital meter is portable and cheap but indicates its output in a range of 0.01 to 9.96 Ω-cm. Values in this range represent conditions when there is little or no moisture in the soil to when there is much water in the soil. With the aid of the calibration curve of the DSMM an appropriate computer program can easily be written to convert the readings in Ohms-centimetre to percentage soil moisture content.

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