Solar Powered Soil Moisture Detector

M.H. Ariff and M.Z. Ibrahim

Abstract**—** These days people love to make money by doing small agricultural scale. The main element must be consider in order to ensure this plants grow steadily is by monitor the moisture content of the soil. Monitoring of soil moisture content in the field calls for a fast and accurate method, which allows repeated measurements through time. One of the popular technique for measuring the spatial distribution and temporal variation of soil moisture content is by use the point measurement. In this paper we present a new electronic device called Solar Powered Soil Moisture Detector to determine the moisture content of the soil .This device use PIC microcontroller where equipped with dielectric sensor where it will communicate and process the dielectric sensor reading and display the exact moisture reading of the soil moisture. In order to generate their own supply, this device also equipped with small solar panel and rechargeable battery. This device is reliable and accurate in determining the moisture content of the soil.

Keywords**—** Solar powered, Point measurement, Dielectric sensor, Moisture content and PIC Microcontroller.

I. Introduction

Most of chemical and physical properties of soil vary with moisture content. Measurement of soil water content is needed in every type of soil study. Agrology, Hydrology and plant science and all require soil moisture data.

Soil moisture content is normally given as a dimensionless ratio of two volumes or two masses. When soil moisture content, given as a dimensionless ratio, is multiplied by 100, the value becomes a percentage on a mass or volume basis. Where no indication of mass or volume is given, soil moisture content is normally on a mass basis. Determination of soil moisture on a volume basis involves finding mass basis figures first. Once mass basis figures are found, volume basis figures are determined using bulk density. Considering the variance in soil, some error is nearly always involved in determining bulk density. The amount of water in soil can also be given as a depth as if it were accumulated in a layer. A depth of water is typically used in irrigation. Specification of a depth of accumulated water is usually accompanied by a modifier such as, "in the rooting zone." [1]-[4]

MH Ariff and M.Z. Ibrahim are with the Faculty of Electrical and Electronics Engineering, Universiti Malaysia Pahang, 25000 Kuantan, Pahang, Malaysia (email: hisyam@ump.edu.my)

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While normal moisture contents given as a dimensionless ratio of two volumes or two masses, soil water dielectric methods are taking place. When a medium is placed in the electric field of a capacitor or waveguide, its influence on the electric forces in that field is expressed as the ratio between the forces in the medium and the forces which would exist in vacuum. This ratio, called permittivity or "dielectric constant", is for liquid water about 20 times larger than that of average dry soil, because water molecules are permanent dipoles [5], [6]. The dielectric properties of ice, and of water bound to the soil matrix, are comparable to those of dry soil. Therefore, the volumetric content of free soil water can be determined from the dielectric characteristics of wet soil by reliable, fast, non-destructive measurement methods, without the potential hazards associated with radioactive devices. Moreover, such dielectric methods can be fully automated for data acquisition. At present, two types of sensor which evaluate soil water dielectrics are commercially available and used extensively, namely time-domain reflectometry (TDM) sensor and frequency domain (FD) sensor .

In frequency domain reflectometry sensor, it measures the dielectric constant at a single microwave megahertz frequency. The microwave dielectric probe utilizes an open-ended coaxial cable and a single reflectometer at the probe tip to measure amplitude and phase at a particular frequency. Soil measurements are referenced to air, and are typically calibrated with dielectric blocks and/or liquids of known dielectric properties. One advantage of using liquids for calibration is that a perfect electrical contact between the probe tip and the material can be maintained. As a single, small probe tip is used, only a small volume of soil is ever evaluated, and soil contact is therefore critical. As a result, this method is excellent for laboratory or point measurements [2].

We developed a new electronic meter called Solar Powered Soil Moisture Detector to determine the volumetric moisture content of soil. This device is equipped with FD sensor and powered by Solar Charging Unit where it able to do point measurement.

This Soil Moisture Meter designed by modules. It consists of hardware and software part. Using a modular approach, parts are easier to implement and troubleshooting can be done easily. Fig.1 shows the architecture of this device. It divided into three parts which is input, microcontroller and output. The input consists of FD sensor to find level of soil moisture and Solar Panel which generate supply to battery charging circuit. The output part consists of LCD display which shows the information on types of soil (dry, balance, wet) and percentage of soil moisture.

This paper organized as follows: Section 2 describes the soil moisture algorithm in details. Section 3 and section 4 describes the hardware and software development. Section 5 described the results and discussion and followed by conclusion in Section 6.

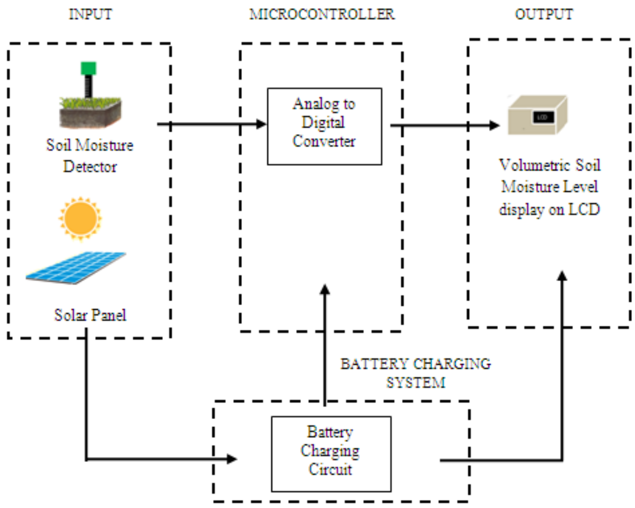

Fig. 1 Architecture of Solar Powered Soil Moisture Meter

II. Algorithm

A. Analog to Digital Converter

In this project, the reading of sensor is in voltage and in analog values. Therefore, analog to digital converter (ADC) is used since Microcontroller only process digital signal for its operations. Resolution of the ADC indicates the number of discrete values it can produce over the range of analog values. The values are usually stored electronically in binary form, so the resolution is usually expressed in bits. In consequence, the number of discrete values available, or "levels", is usually a power of two. For example, in this project, ADC with a resolution of 10 bits can encode an analog input to one in 1024 different levels, since $2^{10} = 1024$. The values can represent the ranges from 0 to 1023 (i.e. unsigned integer) or from -512 to 512 (i.e. signed integer), depending on the application. Resolution can also be defined electrically, and expressed in volts. The voltage resolution of an ADC is equal to its overall voltage measurement range divided by the number of discrete intervals as in the formula [7]:

$$Q = \frac{E_{FSR}}{2^M - 1} = \frac{E_{FS}}{N} \tag{1}$$

where

Q = Resolution in volts per step
E_{FSR} = Full scale voltage range
M = ADC's resolution in bits
N = Number of intervals

In practice, the smallest output code ("0" in an unsigned system) represents a voltage range which is 0.5Q, that is, half the ADC voltage resolution (Q), as does the largest output code. The other $N - 2$ codes are all equal in width and represent the ADC voltage resolution (Q) calculated above. Doing this centers the code on an input voltage that represents the Mth division of the input voltage range. This practice is called "mid-tread" operation. This type of ADC can be modeled mathematically as [8]:

$$ADC_{Code} = \left(round\left(\frac{2^M}{V_{RefHi} - V_{RefLow}} \right) . (V_{in} - V_{RefLow}) \right) \tag{2}$$

The exception to this convention seems to be the Microchip PIC processor, where all M steps are equal width. This practice is called "Mid-Rise with Offset" operation.

$$ADC_{Code} = \left(floor\left(\frac{2^M}{V_{RefHi} - V_{RefLow}} \right) . (V_{in} - V_{RefLow}) \right) \tag{3}$$

where

V_{RefHi} = Maximum voltage measurement
V_{RefLow} = Minimum voltage measurement
V_{In} = Input voltage measurement
M = ADC's resolution in bits

B. Soil Moisture

For this part, the percentage moisture value is obtained by using this formula:

$$Moisture\,(\%) = \frac{res}{1024} \times 100 \tag{4}$$

where

res = result from ADC at microcontroller.

III. Hardware

A. Microcontroller

PIC is a family of Harvard architecture microcontrollers made by Microchip Technology. The name PIC initially referred to "Programmable Interface Controller", but shortly thereafter was renamed "Programmable Intelligent Computer". PICs are popular with developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, serial programming and re-programming with flash memory capability.

During the initial development, PIC 18F2620 was used as microcontroller, but due to its size (28 pins), we change to PIC 18LF14K50 which is smaller size (20 pins) compared to PIC 18F2620. This microprocessor as shown in Fig.2 has high computational performance at an economical price with the addition of high-endurance, Enhanced Flash program memory. All of these features make these microcontrollers a logical choice for many high-performances, power sensitive applications.

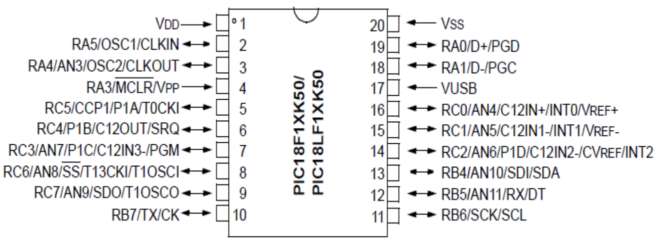

Fig. 2 Microchip PIC 18LF14K50 pin diagram

B. Vegetronix Moisture Sensor Probe

A moisture sensor probe monitors soil moisture reliably in all types of soils at all moisture levels. Soil moisture in fields, turf, landscapes, and greenhouses may be monitored equally well. A typical probe which cans be found easily in any shops is not suitable because it is not handy and expensive in term of cost. The Vegetronix VG400 is latest advanced technology that measures the dielectric constant of the soil using transmission line techniques.

Fig. 3 Honeywell HMC6352

C. Portable Solar Panel

The main component of off-grid Solar Power Soil Moisture Detector systems is the solar panel. Solar panels collect light from the sun and convert it into electrical energy which can then be stored for later use. The fig. 4 shows external solar panel. This part is the main voltage source that will be supplied to the power circuit. The solar panel will produce roughly (8V to 12V) to the power circuit under a well sunshine day.

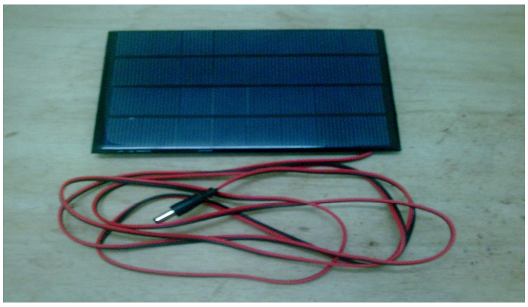

Fig. 4 Solar panel

IV. Software

PIC microcontroller is a special-purpose integrated circuit designed to perform one or a few dedicated function depending on code integrated inside it. It is usually embedded as part of a complete device including hardware and mechanical parts. The code is writing using programming language such as c or basic that provides a structured mechanism for defining pieces of data, and the operations or transformations that to be carried by microcontroller.

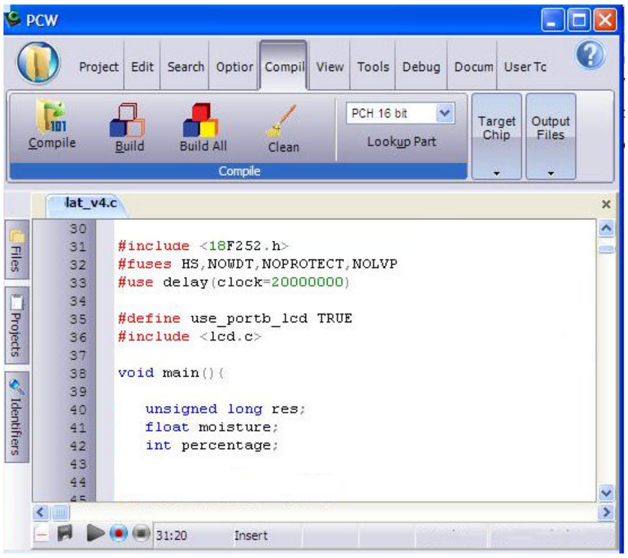

Fig. 5 CCS C Compiler IDE

CCS C Compiler which has been developed exclusively for the PIC microcontroller has a generous library of built-in functions, preprocessor commands, and ready-to-run example programs to quickly jump-start any project. It has Microsoft Window based Integrated Development Environment (IDE) compiler that capable to aid in program design and editing. Features of the IDE include a color syntax editor, a powerful C Aware Real-time Debugger, RTOS, linker, and a New Project Wizard for peripherals and drivers.

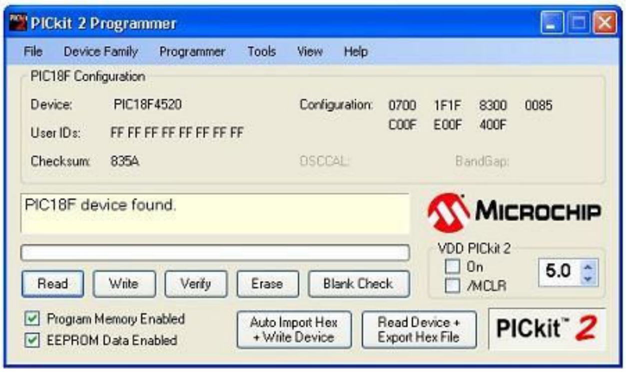

Fig. 6 PICKit 2 Programmer Software

The PICKit 2 Programmer is a Windows PC application that provides a simplified, feature rich interface for PICkit 2 device. It will transfer the code to PIC microcontroller through PICKit 2 device.

V. RESULTS

A. Image of Embodiment

This section as in Fig. 7 shows the image of embodied detector. There are two functions that can be displayed on the device which are:

1) Indicator of battery level
2) Level of moisture for soil (moisture value range, soil condition, percentage of soil moisture)

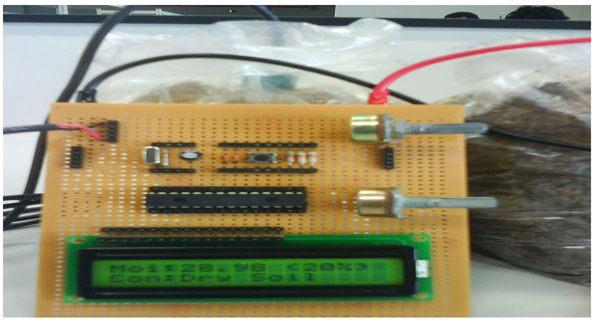

Fig. 7 Image of embodiment

Fig. 8 shows the battery monitoring unit. The function of this unit is to monitor the level of battery charging. The source of voltage (5V) for this circuit is supplied by the solar panel through the power circuit. The LEDs are consisting of three colors (red, yellow and green). Each color indicates different level of battery charged. Red color indicates that the battery charged is still in low level, yellow color indicates that the battery charged is in medium level and the green color indicates the battery is fully charged or the battery charged is in high level.

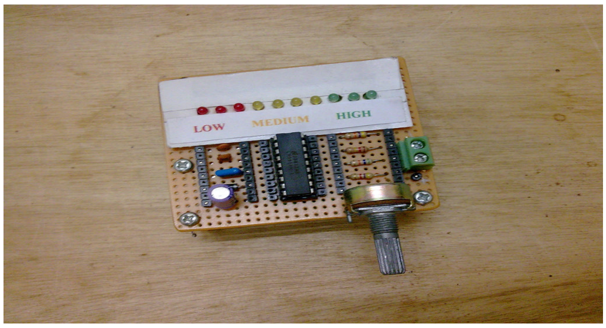

Fig. 8 Battery Monitoring Unit

Fig. 9 shows the moisture range, soil condition and percentage of soil moisture. This parameter is important element before start to plant.

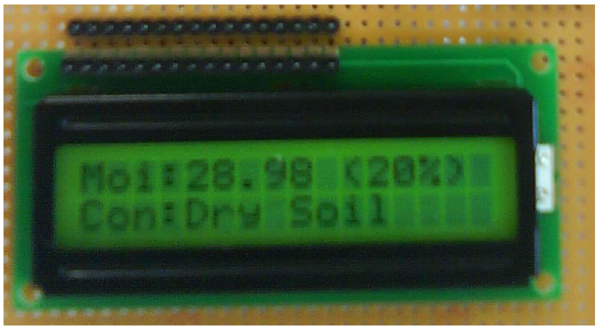

Fig. 9 Information displayed for Soil Condition

B. Performance evaluation

The performance of this detector was tested by the depth of sensor placement from the surface of soil. The second test is to find the range to decide the condition for the soil such as dry, balanced and wet.

The test was taken in a laboratory environment. For the first test, we put 5L water in a 5 kg of soil in a soil bag. We compared and analyzed the data obtained from two digital soil moisture meters and the performance guaranteed soil moisture meter attached to the soil bag. We compared the metering value from our soil moisture detector and the performance guaranteed water meter. As Table 1 shows, we got unanimous result in 10 cm displacement. For 5cm and 7cm displacement, there were little errors. In this paper, the 10cm displacement of FD sensor is decided the most appropriate.

For this second test it takes 1 week to complete since all the soil moisture measurement counts from the dry condition and we poured it with 5L water in a 5 kg of a soil bag. This measurement stopped when the soil detector shows the dry condition readings. Table 2 shows the result for the second test of the soil moisture and the soil condition on LCD when the FD sensor is placed in the tested soil.

Num	5cm displacement (% of soil moisture)	7cm displacement (% of soil moisture)	10cm displacement (% of soil moisture)
1	85	88	92
2	85	87	91
3	86	87	92
4	85	86	92
5	85	88	90
6	84	86	91
7	85	87	92
8	86	86	94
9	85	88	92

Table 1 Results of performance evaluation of FD sensor in displacement

Tested soil type	Measured soil moisture value (range)	Soil condition displayed on LCD	Percentage of soil moisture (%)
No condition	(<5)	-	0 - 2
Dry	(≥5,<59)	Dry soil	2 - 29
Balance	(≥59,<79)	Balance soil	30 - 39
Wet	(≥79,<200)	Wet soil	40 - 100

Table 2 Results of soil moisture on different soil condition

VI. Conclusion

In this paper “Solar Powered Soil Moisture Detector” has been presented to determine the moisture content of soil. All the design and embodiment of this soil detector is described. The device powered by solar charging system provides some information of the soil moisture value range, percentage of soil moisture and condition of the soil.

This device integrates several features and functions that make it prominent form others. In most products, determination of soil moisture will be based on chemical kit and some of the device required complicated setting before doing the measurement.

This system is reliable, user friendly and can be placed in the ground for a long time since the system generates power from solar charging system.

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