Development of Soil Moisture Monitoring Device for Irrigation Water Scheduling

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Abstract

Farmers need to rely on some methods of determining the water needs of their crops to avoid production and quality losses. In this work, a soil moisture monitoring device has been developed. It is capable of monitoring soil moisture level at the root zone of the crops and can also send short message service (SMS) to the farmer on his mobile phone when the threshold value is reached, either when irrigating or depletion of the soil moisture. The device comprises of three major units; input unit made up of YL-69 soil moisture sensor, control unit made up of PIC16F877A microcontroller and the output unit; which comprises of GSM module SIM9000A and 16x2 LCD screen. Device's performance carried out/determined at 0-60% output range setting. From the experimental result on the developed soil moisture device, first-day reading obtained at 0-60% output range was 56%. Also, readings from soil moisture meter and gravimetric method on the same day were found to be 55% and 52.5%, respectively. The result indicates the effectiveness of the device. Furthermore, from the result obtained by calibrating the device at 0-60% output range with the gravimetric output gives the coefficient of determination (R^2) values of 0.9808. These values indicate a strong linear correlation relationship.

Keywords: Soil moisture sensor, Irrigation scheduling, Monitoring device, Gravimetric method.

Introduction

Crops require water to grow and produce good yields. When the crop is water stressed they close their stomata and cannot photosynthesis effectively (Bernie, 2000). Best growth can be achieved only if plants have a suitable balance of water and air in their root zones. Some stages in the growth of a crop are particularly sensitive to moisture stress. Water shortage sufficient to hinder crop growth can occur without producing obvious wilting of foliage, while waterlogging can cause large yield reductions. The farmer must therefore, rely on some other method of determining the water needs of the crops to avoid production or quality losses. This requires an understanding of the movement and storage of water in the root zone of the crop and the rate of water use by the crop (Bernie, 2000).

Measurement of soil water is essential for proper scheduling of irrigation and estimating the amount of water needed for irrigation. Since soil water is dynamic, knowledge on the change in soil water content from time to time is important for proper monitoring of water management practice both in irrigated and rain fed farming. Several methods have been developed for measurement of soil water (Majumdar, 2010).

The decision of when to irrigate is usually based on; past experiences, weather-based information (crop evapotranspiration data), or soil-based measurements. Past experiences may not be correct and are often not adjusted for annual changes in weather. Scheduling irrigations based on crop evapotranspiration can be difficult because it is hard to obtain accurate data for some locations and, even when data are available, the task of keeping track of evapotranspiration data for individual fields can be time consuming. Due to the difficulties and shortcomings of these methods, soil based irrigation scheduling may be the preferred technique (Heiniger, 2013).

Therefore, the objective of this work is to develop simple and affordable moisture monitoring device for irrigation water scheduling.

Materials and Methods

This developed device has three major units; input unit, control unit and the output unit. The input unit comprises of soil moisture sensor for sensing the moisture content of the soil and two potentiometers for setting the threshold by the user. YL-69 soil moisture sensor (a resistance type sensor) was used in this work. The control unit was achieved using PIC16F877A microcontroller. GSM module SIM900A and 16x2 LCD (liquid crystal display) screen are used in the output unit. The GSM module sends SMS message to the user at the upper and lower threshold set by the user himself while the LCD screen displays the soil moisture content. Micron C compiler software was used to develop the program. The block diagram for hardware connections is shown in Figure 1.

Power supply unit

The power supply unit uses a battery of 12 V to supply dc voltage to the circuit and regulated to 5V by LM7805 regulator as required by the device as shown in Table 1.

Soil moisture sensor

This unit consists of soil moisture sensor for monitoring conductivity and resistivity of the soil; variable resistor for the moisture probe. Copper rod has been used to measure the resistance of the soil between the two probes.

Table 1. Total Current Estimation to the Circuit

Components List	**Quantity**	**Current(mA)**	**Total current (mA)**
PIC16F877A	1	25	25
GSM module	1	100	100
LCD	1	30	30
Moisture sensor	1	35	35

Total = 190mA. The battery voltage=12V The current = 2A

If the soil is wet to saturation the resistance between the two probe will be $R_{moisture}$= 0Ω and if the soil is completely dry the resistance between the two probe will be R_{dry}=8.6kΩ. The soil moisture detecting circuit is shown in Figure 1. The R_{v1} (variable resistor) obtained by equation (1) was used to control the output signal from the sensor which was connected to port AO of microcontroller, thus the output range of the device can be adjusted.

The resistance of soil moisture is 8.6kΩ. Then R_{v1} is calculated below by choosing the followings (Theraja 2011).

$$V_{out} = \frac{Vcc \times Rv1}{Rv1 + R(dry)} \quad (1)$$

Where, V_{out} = voltage output from the sensor, V_{cc} = voltage input to the sensor, and R_{dry}= resistance between the two probe in dry condition.

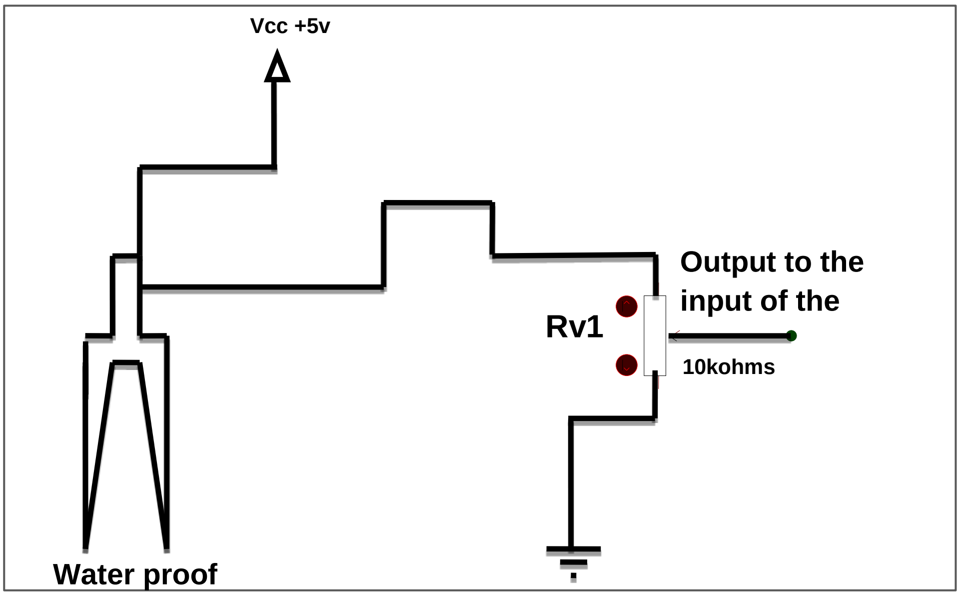

Figure 1. Soil Moisture Detecting Circuit (Theraja 2011)

Control unit

A Microcontroller is a small computer on a signal integrated circuit containing a processor core, memory and programmable input/output peripherals (Amanullah, 2013). This unit controls the entire output unit like, LCD and the GSM module while monitoring the input signals from the soil moisture sensor and the set threshold. The PIC16F877A was used in this unit due to it is very easy to program (Huthaifa e*t al., 2016*).

Liquid crystal display (LCD) Interface PIC16F877A

16x2 LCD screen was used to display the moisture content because it can be easily programmed. It has no limitation of displaying special and even custom characters, animations and so on.

SMS reporting unit

This unit is responsible for sending SMS to the user mobile when moisture is low or high as set by the user. For sending message GSM Module SIM900A was used in this work. GSM Module SIM900A with SIM-card holder, RS232 interfaces. The GSM Module is interface with microcontroller directly through port C of the microcontroller. GSM Module works with AT COMMANDS. Attention (AT) commands was used to control MODEMS Figure 2. Shows the interface between PIC16F877A microcontroller and GSM Module SIM900A.

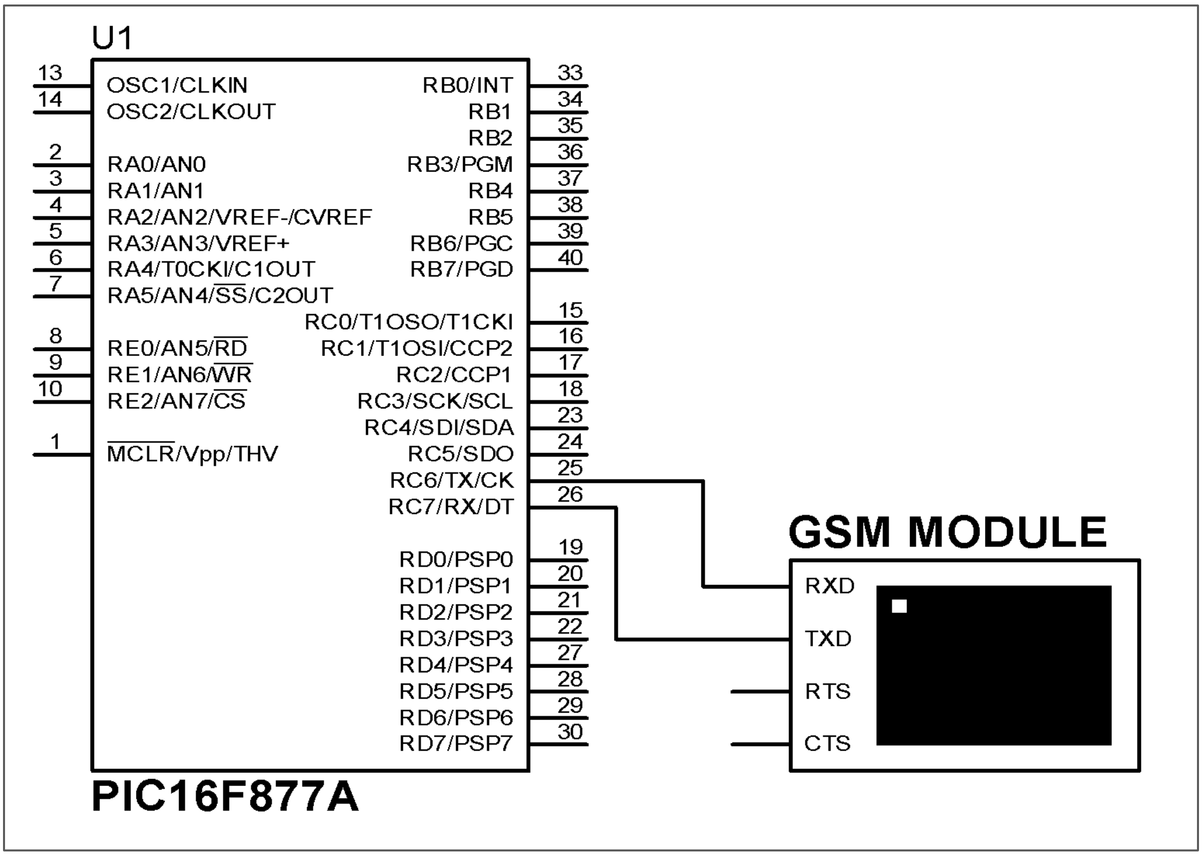

Figure 2. GSM Module PIC16F877A Interface

The software design

Program flowchart was developed as shown in Figure 3. First the device initializes and the user input the maximum and minimum threshold of the moisture content that is required for the device to send message. If the moisture content reach any of the threshold value set by the user, short message service is send to the user notifying him of the statues of the moisture content as program. The program was developed using mikro C pro for PIC.

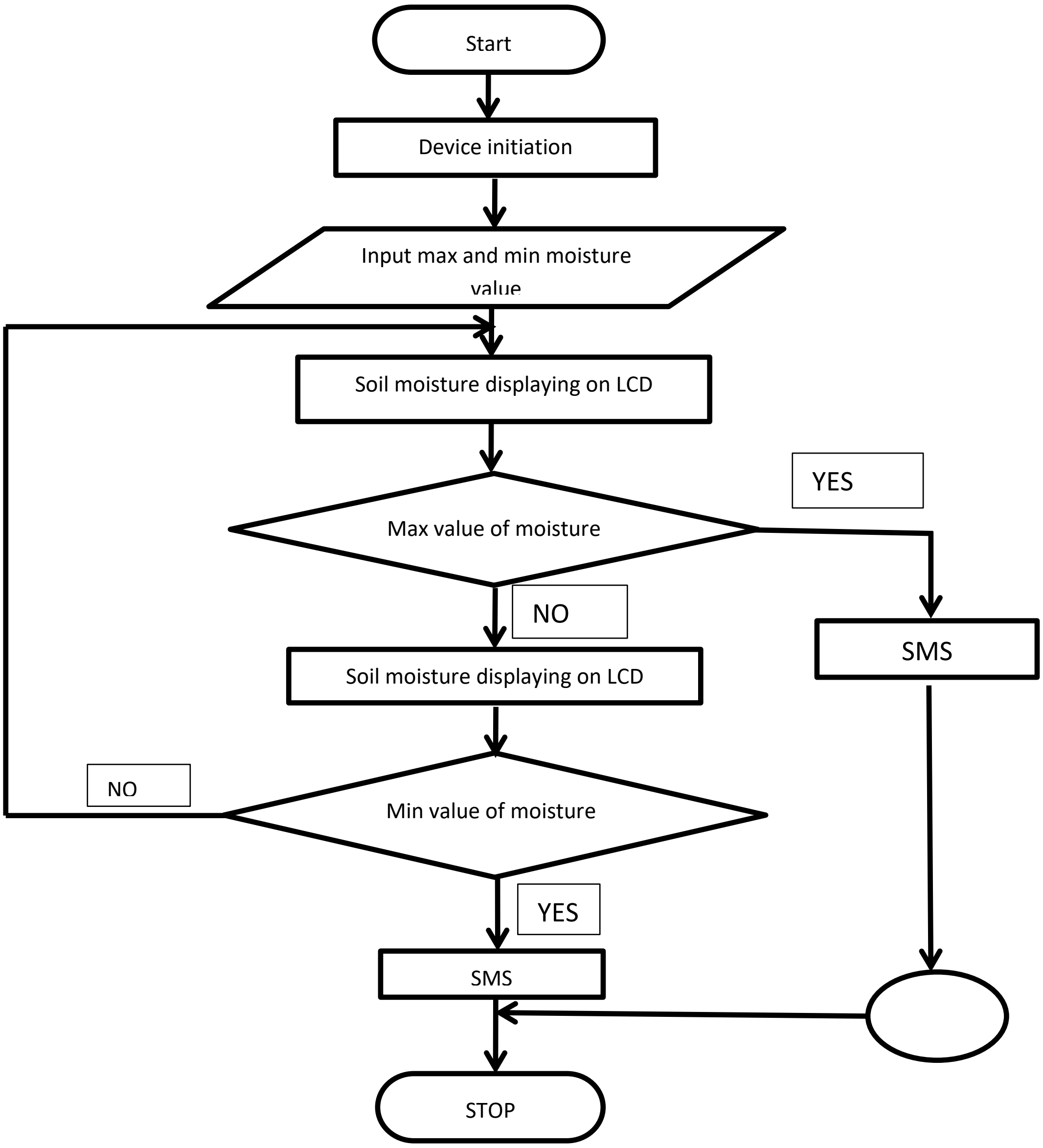

Figure 3. System Flow Chart

Simulation Diagram

The simulation diagram developed using proteus software, while mikronC pro for PIC software used to develop the program as shown in Figure 4. The simulation gave the desired result into the microcontroller.

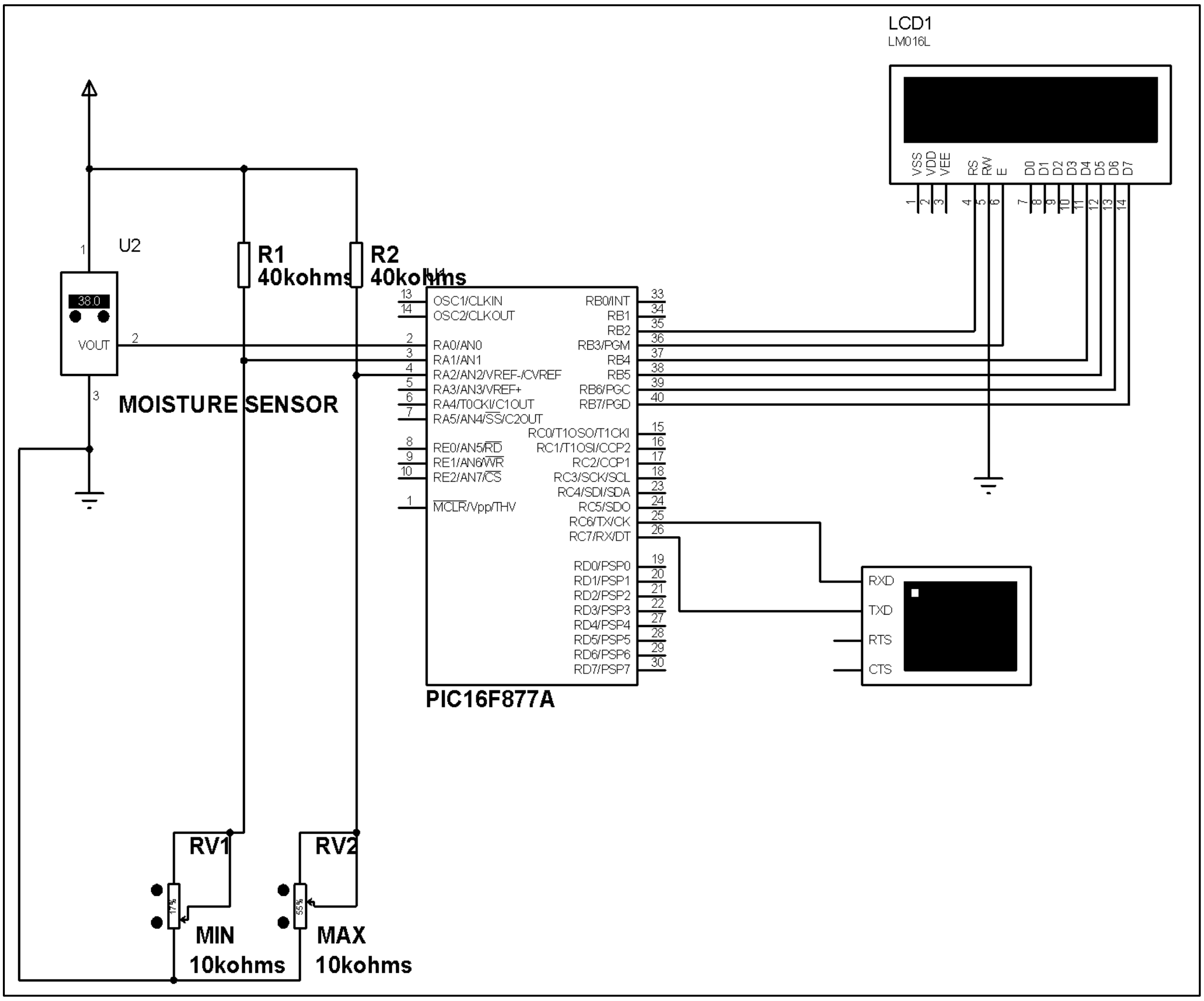

Figure 4. Simulation Diagram

Circuit design

Circuit is a continuous conducting path where electric current can flow. It comprises of various electrical element. The complete circuit design for the device is shown in Figure 5. This encompasses all the subunits that were described.

Device testing

After construction, tests were carried out on the device to ensure that the device is functioning according to the design specifications. The test conducted on the device is to verify the level of conformity of the output of the device. Soil sample was collected from the field and placed inside the perforated plastic container. The soil then undergoes continued wetting every day for a week in order to give the soil some level of compaction inside the container. Then water was added to the soil inside the container until it reaches saturation point and the water was drained gravitationally through the perforation. The Soil sensor was then placed at a depth of 5 cm in the soil and the output readings were taken at 0-60% output range setting of the device

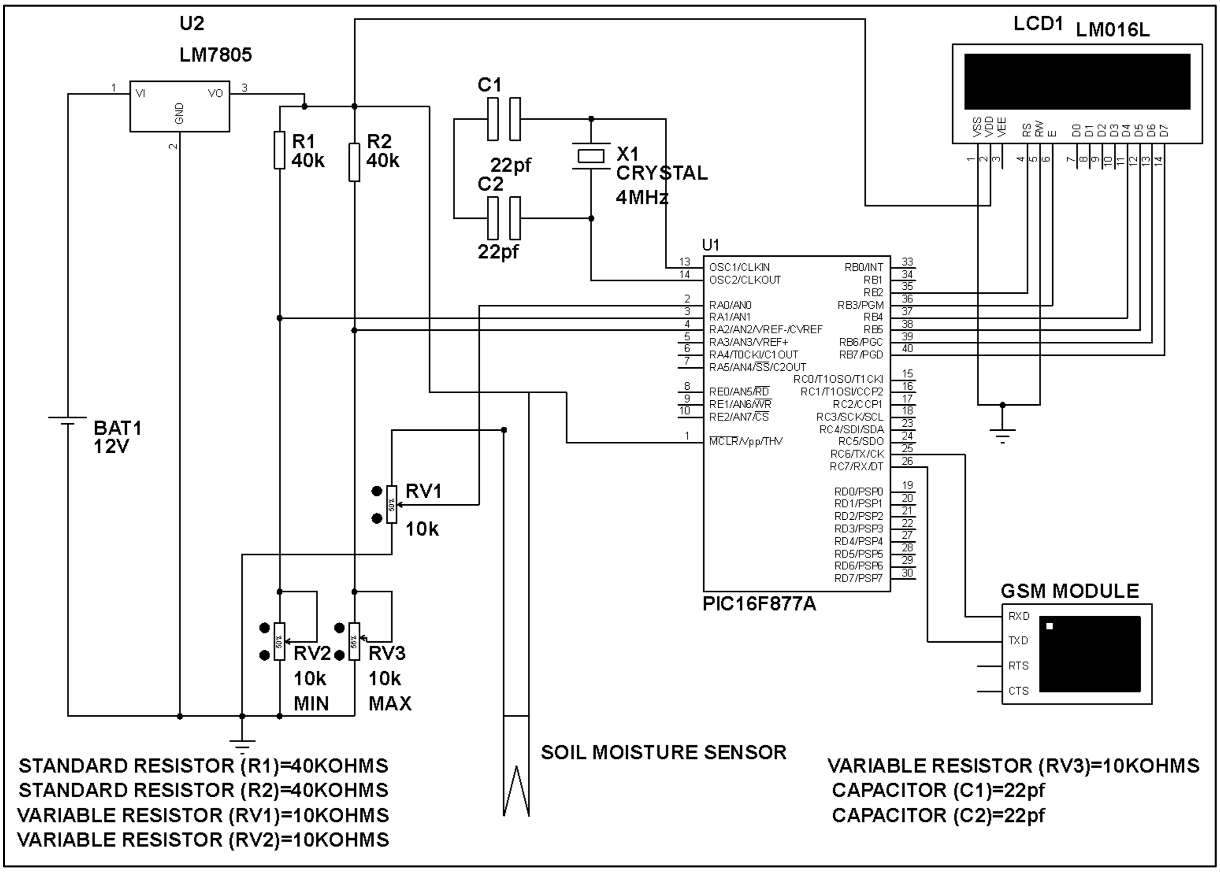

Figure 5. Circuit Design

On other hand, soil moisture levels were also determine using conventional soil moisture meter and gravimetric method for comparison.

Results and Discussion

Figure 6 shows the complete device setup for soil water monitoring. The result was obtained at 0-60% output range setting when the test was conducted. As can be seen from Figure 7. The soil moisture levels reading from the developed device, conventional moisture meter and gravimetric method shows similar trend having little differences. This indicated the effectiveness of the developed device. However, further performance evaluation will be conducted on the field irrigated crops. It is important here to note that the output range of the device can be varied by the user through a potentiometer (variable resistor) inside the device. Whenever standardization is require to be made with any other moisture monitoring device.

Device calibration

The device calibration graph at 0-60% is shown in Figure 8. Gravimetric output is on vertical axis against developed device output on horizontal -axis. The coefficient of determination (R^2) value was 0.9809.

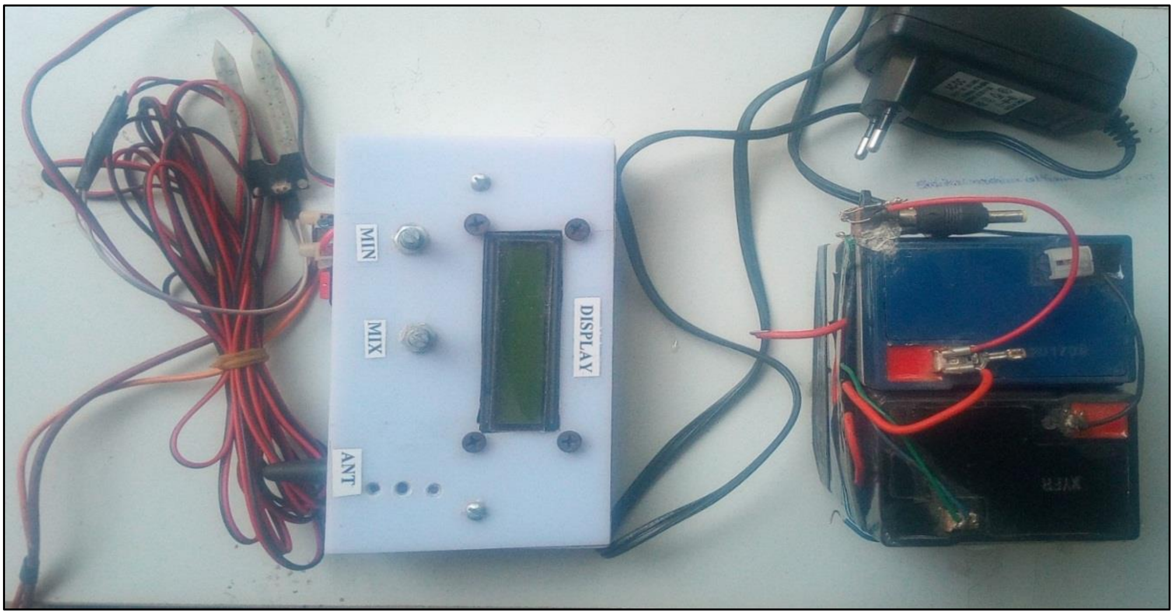

Figure 6. Device Setup

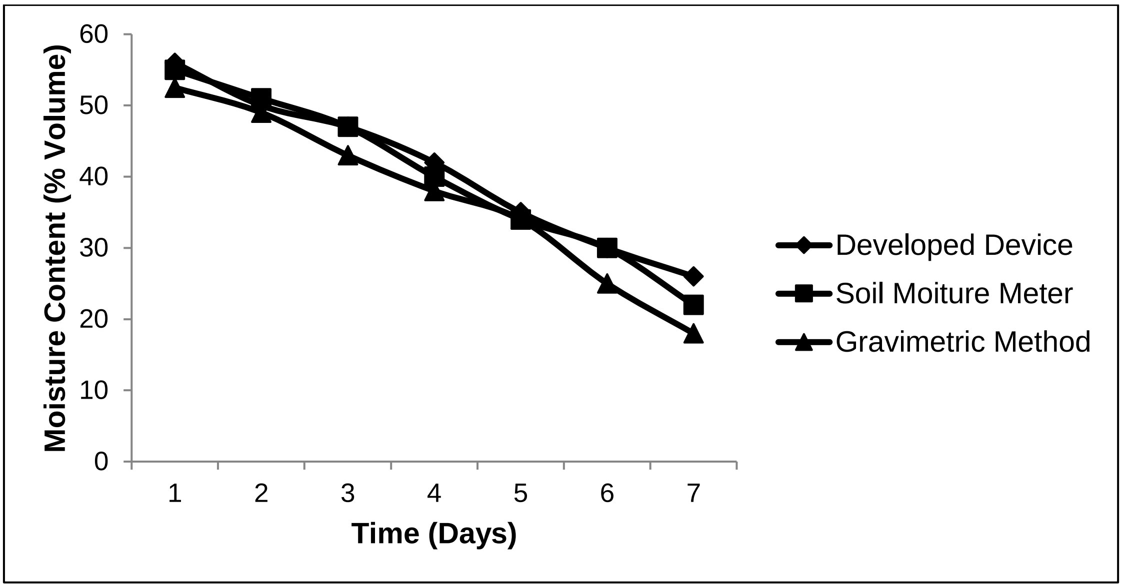

Figure 7. Soil moisture readings from the developed device, soil moisture meter and gravimetric Method

This linear regression equations can be used to determine the actual gravimetric moisture content by using the value of the output from the device as unknown value in the equation and the coefficient of linear regression values indicate a strong linear relationship, between the device and gravimetric moisture content.

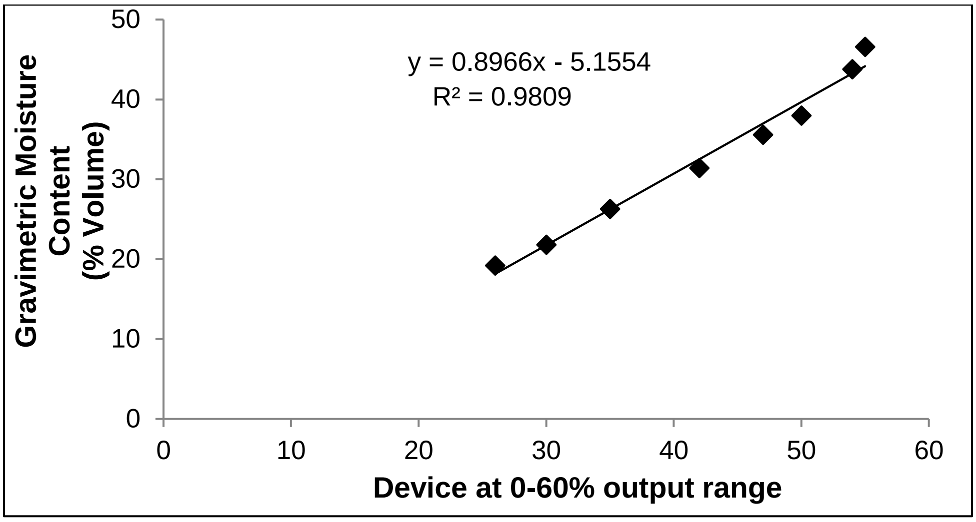

Figure 8. Device Calibration at 0-60% Output Range

Conclusion

In this work, soil moisture monitoring device was successively assembled, calibrated and tested. The test conducted on the device was found to operate based on the developed program. Moisture content can be monitor on the device and it is also capable of sending short message service. The device will provide an alternative choice for automatic irrigation system. Furthermore, from the result obtained by calibrating the device at 0-60% moisture content output range with the gravimetric output gives coefficient of determination (R^2) values as 0.9809. These values indicate a strong linear relationship, between the device and gravimetric moisture content.

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