

Development of a Soil Moisture Control System with PC Monitoring

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ABSTRACT

The purpose of this study is to develop an irrigation system flow control valve consisting of conjunction channels through a personal computer (PC) batch to monitor the water flow into a specific area of soil when it reaches a lowest moisture level (threshold), i.e. somewhat dry. When the soil moisture reaches the threshold of specific moisture content, the control valve opens for a specified period of time to moisten that spot of soil. When the moisture content reaches the threshold, the valve is closed.

The valve control was fitted to the outlet of the water tank. The valve electric supply was controlled by the sensor monitor system so that water was flowing through it and reaches into the soil. When the electricity was cut from the valve, this closed the valve and stopped pumping water to the soil.

A computer program was developed to monitor the soil moisture sensor and the water valve.

Key words: soil moisture, electric valve, soil moisture sensor, control system, electronic circuits.

INTRODUCTION

Irrigation water is essential for profitable crop production in most of the arid land. Proper irrigation management is a key for high yields and to avoid stress from too much or too little water. Improper irrigation management limits yields more often and to a greater degree than any other production factor. The misuse and waste of water especially in the field of irrigation as a result, water scarcity, which lead to deprive some areas. The wrong utilization of water as a resource occurs throughout the growing season - generally too much is used at the beginning and the end of the season, and too little during the peak period. Therefore, it requires control of the wealth and organization of water use and conservation with finding ways to increase storage in situations for use when needed.

Soil Basics

Soils are one of the most important resources a farmer has. Soil health is fundamental to profitable and sustainable production. How we manage nutrients, organic matter and microbial populations is a key to building soil health. There is a series of fact sheets on soil basics discussing physical and chemical properties of soils, soil organic matter and using soil tests as a tool in building and managing nutrients and soil quality (Howell, 2008).

Soils are composed of solid particles which have spaces between them. The soil particles consist of tiny bits of minerals and organic matter. The spaces between them are called pore spaces and are filled with air and water. It is desirable for an agricultural soil to have about one-half soil particles and one-half pore spaces by volume. Ideally, in mineral soils, organic matter accounts for 5% or less of the weight of solid particles. Moisture content varies considerably with factors such as soil drainage and the amount and frequency of rain or irrigation. For most agricultural crops conditions are best when the pore spaces are filled about equally with water and air (Howell, 2007)... Fig. (1) Shows the composition of soil by volume.

Measuring Soil Moisture for Irrigation Water Management

Irrigation water management requires timely application of the right amount of water. Competition for water, high pumping costs, and concerns for the environment are making good water management more important. Managing irrigation water needs to combine a method of measuring soil moisture with some method of irrigation scheduling.

Measuring soil moisture detects if there is a water shortage that can reduce yields or if there is excessive water application that can result in water logging or leaching of nitrates below the root zone. Measuring soil moisture also can build an awareness and knowledge of each irrigated field that is invaluable for planning and management. Monitoring soil moisture levels is required for effective irrigation water management. Many tried and proven methods of estimating or measuring soil moisture are available. The method selected depends on a variety of factors such as accuracy, cost, and ease of use.

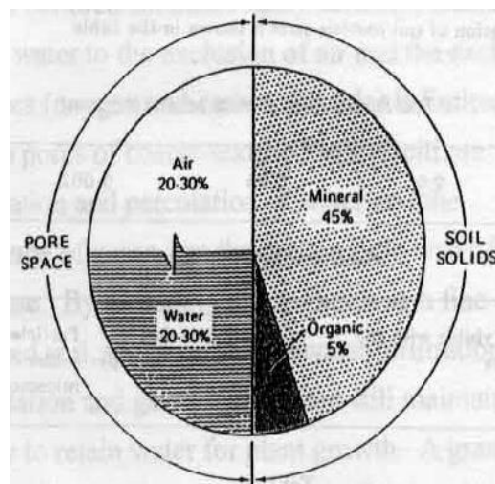


Fig. 1. Composition of the soil by volume (Howell, 2008)

Soil Moisture Concepts and Terms

Soil water potential describes how tightly the water is held in the soil. Soil tension is another term used to describe soil water potential. It is an indicator of how hard a plant must work to get water from the soil the drier the soil, the greater the soil water potential and the harder it is to

extract water from the soil. To convert from soil water content to soil water potential requires information on soil water versus soil tension that is available for many soils.

Water in the soil is classed as available or unavailable water. Available water is defined as the water held in the soil between field capacity and wilting point as shown in Fig. 2.

Field capacity is the point at which the gravitational or easily drained water has drained from the soil. Traditionally, it has been considered as 1/3 bar tension. However, field capacity for sandy soils is approximately 1/10 bar tension.

Wilting point is the soil moisture content where most plants would experience permanent wilting and is considered to occur at 15 bars tension. Table 1 gives common ranges of available water for soil types (Werner, 2002).

Readily available water is that portion of the available water that is relatively easy for a plant to use. It is common to consider about 50% of the available water as readily available water. Even though all of the available water can be used by the plant, the closer the soil is to the wilting point, the harder it is for the plants to use the water. Plant stress and yield loss are possible after the readily available water has been depleted.

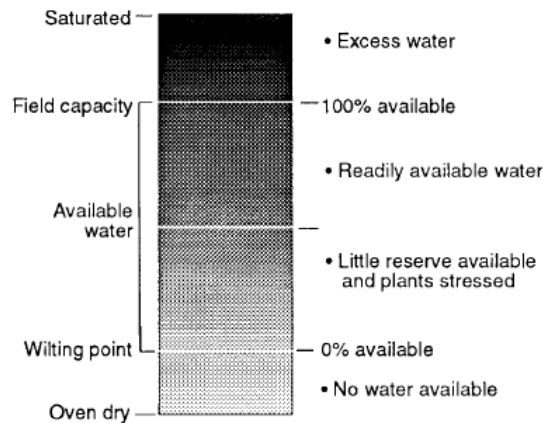


Fig. 2. Available water in the soil (Werner, 2002)

Table1. Available water capacities for various soil types (Werner, 2002)

Soil Type	Centimeters of water per 1/3 meter soil
Fine sand	1.78 - 2.54
Loamy sands	2.29 - 3.81
Sandy loams	3.30 - 4.57
Loams	4.57 - 6.35
Silt loams	4.57 - 6.60
Clay loams	4.57 - 6.35
Clays	4.57 - 6.1

Irrigation Valves

An irrigation valve is an automatic valve, typically an electric solenoid type valve that is installed at the point where the irrigation system connects to the water supply. The irrigation valve is wired to a special "irrigation valve circuit" on the irrigation controller. (Sometimes this circuit is called a "pump start circuit". Both types of circuits work similarly or identical, and can be used for a pump and/or an irrigation valve.) The irrigation controller turns the irrigation valve on and off. Most, but not all, irrigation controllers have an irrigation valve circuit built into them.

Work of an irrigation valve

The open and close of the control valves were based on water pressure (specifically pressure differences). There are two main areas inside the valve called the "upper chamber" and "lower chamber. These two chambers are separated by the diaphragm. Water flows into and fills the lower chamber. A small tube in the middle of the diaphragm allows water to flow from the lower chamber into the upper chamber. At this point water has filled the upper and lower chambers and water pressure is equal on both sides of the diaphragm. Now the force of the spring pressing on the top side of the diaphragm must be considered. The force from the spring creates a pressure imbalance (the pressure is greater on top) and the diaphragm is held closed. This is the valve's resting normally closed state.

In order for the valve to open the pressure on top of the diaphragm we must be relieved. This is done electronically by the timer via the solenoid OR manually via the manual bleed screw. In either case, when pressure is relieved on top of the diaphragm the water pressure from the lower chamber pushes the diaphragm up and water spills over the lower chamber walls and flows out to the sprinklers. The valve will stay open until pressure is re-applied to the top of the diaphragm. When the timer cuts power to the valve's solenoid the pressure is instantly re-applied to the top of the diaphragm, the valve closes, and returns to its resting normally closed state. When the valve is opened manually and the manual bleed screw is tightened, it may take several minutes for pressure to build up on top of the diaphragm and the valve to close (Pioneer Midwest, 2003).

Flow control

Some valves have a built in flow control device. A flow control device does exactly what it is named for; it controls the flow of water through the valve. A flow control device is simply a mechanical device that restricts the amount of water at which the diaphragm will open. The diaphragm can be restricted 0-100% by the flow control device. Without a flow control device a valve is either 100% open or 100% closed. A flow control device is usually a handle or a screw located on top of the valve. Turning the flow control device clockwise will decrease the flow through the valve. Conversely, turning the flow control device counterclockwise will increase flow through the valve (Pioneer Midwest, 2003).

Control System

The heart of every automation solution is a controller for controlling and feedback control tasks. (Engdahl, 2006). PC Based instrumentation and control is a guide to implementing computer control, instrumentation and data acquisition using a standard PC and some of the most popular computer languages. Numerous examples of configurations and working circuits, as well as representative software make these practical, hands –on guide to implementing PC based testing and calibration systems and increasing efficiency without compromising quality or reliability (Tooley, 2003).

A control system is a device or set of devices to manage, command, direct or regulate the behavior of other devices or systems (Siemens, 2008).

A control system is a collection of components working together under the direction of some machine intelligence. In most cases, electronic circuits provide the intelligence, and electromechanical components such as sensors and motors provide the interface to the physical world. A good example is the modern automobile. Various sensors supply the on-board computer with information about the engine's condition. The computer then calculates the precise amount of fuel to be injected into the engine and adjusts the ignition timing. The mechanical parts of the system include the engine, transmission, wheels, and so on. To design, diagnose, or repair these sophisticated systems, one must understand the electronics, the mechanics, and control system principles. In days past, so-called automatic machines or processes were controlled either by analog electronic circuits or circuits using switches, relays, and timers. Since the advent of the inexpensive microprocessor, more and more devices and systems are being redesigned to incorporate a microprocessor controller. Examples include copying machines, soft-drink machines, robots, and industrial process controllers. Many of these machines are taking advantage of the increased processing power that comes with the microprocessor and, as a consequence, are becoming more sophisticated and are including new features. Taking again the modern automobile as an example, the original motivation for the on-board computer was to replace the mechanical and vacuum-driven subsystems used in the distributor and carburetor. Once a computer was in the design, however, making the system more sophisticated was relatively easy for example, self-adjusting fuel/air ratio for changes in altitude. Also, features such as computer-assisted engine diagnostics could be had without much additional cost. This trend toward computerized control will no doubt continue in the future (Kilian, 2000).

Control Theory

Control theory is an interdisciplinary branch of engineering and mathematics that deals with the behavior of dynamical systems. The desired output of a system is called the reference. When one or more output variables of a system need to follow a certain reference over time, a controller manipulates the inputs to a system to obtain the desired effect on the output of the system.

The concept of the feedback loop to control the dynamic behavior of the reference: this is negative feedback because the sensed value is subtracted from the desired value to create the error signal which is amplified by the controller as shown in Fig. 3 (Wikipedia, 2008).

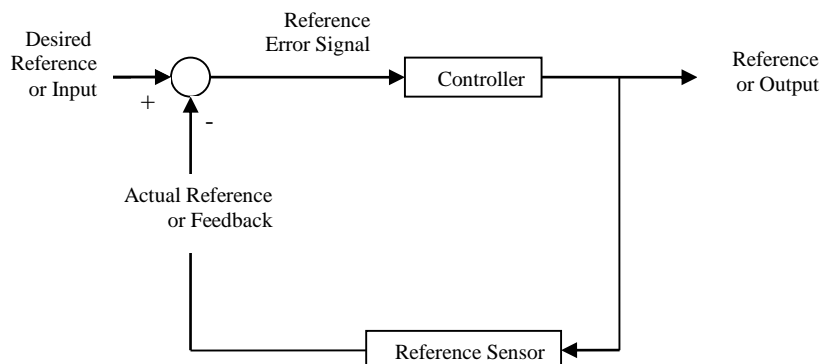


Fig. 3. Control System

System Design

Fig. 4 shows the practical design of soil moisture control using the computer. The objective of design is to read the soil moisture by the sensor circuit, sends the signal result to the LPT1, then the PC takes an action consequently from the program code that is written to display the status of both, the sensor and the solenoid valve.

The design implementation process depends mainly on two parts, the hardware and software tools that could be classified as follows:

- The components of the hardware tools are sensor, optical coupler, voltage regulator, Darlington arrays driver circuit and solenoid valve.
- The components of the software tools are the code written in C language and flow chart that clarifies this code.

Hardware Description

Sensor

The researcher connects the two sensors' probes at the initial point with the soil at an appropriate depth (3 – 5 inch). The sensor circuit explains how soil moisture work. When the sensor probes electrode does not catch any water, the LED circuit will not light. That it is an open circuit that cannot conduct current. Then the solenoid valve will open and allow water to flow to the dry area of soil. When the sensor probe electrode seases water, the LED circuit will light. Then the valve will close and the water stops flow.

The main component of the sensor part is the operational amplifier (op amp) and in this design LM324 was used. This device consists of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single power supply over wide range of voltages The assumption of the op amp is that it compares between two voltages (V_1 & V_2) in the passing stages through inverting and noninverting inputs as follow:-

- V_1 which is dropped by the circuit power supply 9v (circuit reference) with the resistors 220k Ω and 100k Ω respectively that go to the op amp through inverting input (pin 13).
- Versus V_2 which is dropped by the circuit power supply 9v (circuit reference) with the capacitor (100 μ F, 50 v) and resistors 270k Ω and 100k Ω respectively that go through noninverting input (pin 12).

The output of this comparison (pin 14) is amplified through the other op amp (pin 2 and pin 1) and the output (pin 3) is connected to the octal high voltage, high current Darlington Arrays.

Optical High Voltage, High Current Darlington Arrays

The eight NPN Darlington connected transistors (ULN2803) in this family of arrays are ideally suited for interfacing between low logic level digital circuitry (output from pin 3 of the op amp) and the higher current/voltage requirements solenoid valve or other similar loads for a broad range of computer, industrial, and consumer applications.

Solenoid Valve – Dry NC (Normally Closed)

It is direct acting, total isolation solenoid valve, the actuator is totally isolated from the fluid so that the wetted parts are just the body.

When the sensor circuit turns off, that means no water is found in the soil area, so the solenoid valve will receive the signal from Darlington driver, then it closes and water flows to the specific area of soil.

Voltage Regulator KA7805

The function of the voltage regulator is to convert the 9v input to 5v output which is a unique choice that is needed to supply the optical coupler.

Optical Coupler 4N35

Is a 6-pin dip opt isolator transistor output consists of a gallium arsenide infrared emitting diode optically coupled to the monolithic silicon phototransistor detector. The purpose of this device is interfacing and coupling systems of different potentials and impedances. In this application the optical coupler is used to interface the status of the control circuit to the PC through the local printer terminal (LPT).

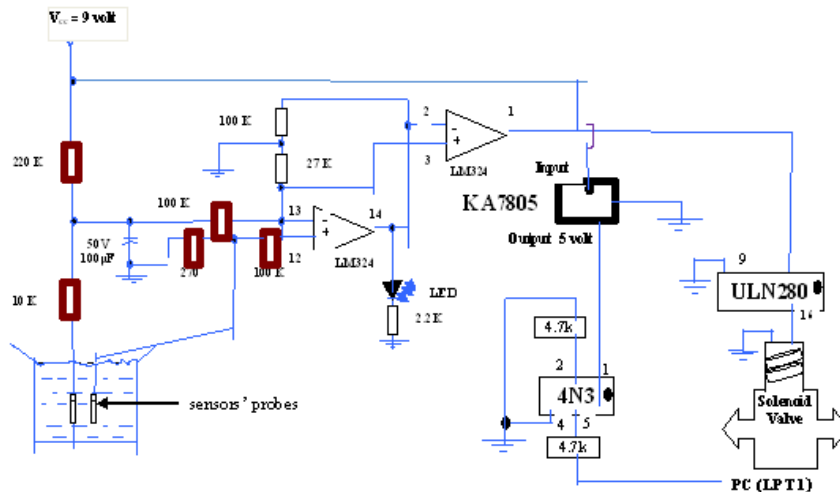


Figure 4. Circuit Diagram of Soil Moisture System

Software Description

The main purpose of this program is to monitor and control the soil moisture and the solenoid valve. The program is written in C language as follows:

```
#include<stdio.h>
#include<conio.h>
#include<dos.h>
#define DATA 0x03bc
#define STATUS DATA+1
#define CONTROL DATA+2
```

```

int main ()
{
int sensor;
// for graphic
Clrscr ();
Text mode (1);
Gotoxy (3, 5);
Text color (WHITE);
Text background (GREEN);
Cprintf ("\n DEVELOPMENT OF SOIL MOISTURE CONTROL");
Text mode (1);
Gotoxy (8, 8);
Text color (WHITE);
Text background (GREEN);
Cprintf ("\n SYSTEM WITH PC MONITORING");
Gotoxy (5, 14);
Text color (WHITE+BLINK);
Text background (RED);
Cprintf ("SOIL MOISTURE");
Gotoxy (24, 14);
Text color (WHITE+BLINK);
Text background (RED);
Cprintf ("VALVE STATUS");
Text mode (1);
Gotoxy (5, 16);
Text color (WHITE);
Text background (RED);
Cprintf ("Is Water Found?");
Text mode (1);
Gotoxy (24, 16);
Text color (WHITE);
Text background (RED);
Cprintf ("The VALVE is");
Read Sensor:
Sensor=inportb (STATUS);
If (((sensor^0x80) &0x80) ==0) goto open valve;
Gotoxy (5, 17);
Cprintf (" YES ");
Gotoxy (24, 17);
Cprintf (" CLOSE");
Goto read Sensor;

Open valve:
Outpost (DATA,0X00);
Gotoxy (5,17);
cprintf (" NO ");
Gotoxy (24,17);
Cprintf (" OPEN");
Goto read Sensor;
Finish:
getch ();
return (0);
}

```

The flow chart in Fig. 5 illustrates the program cycle

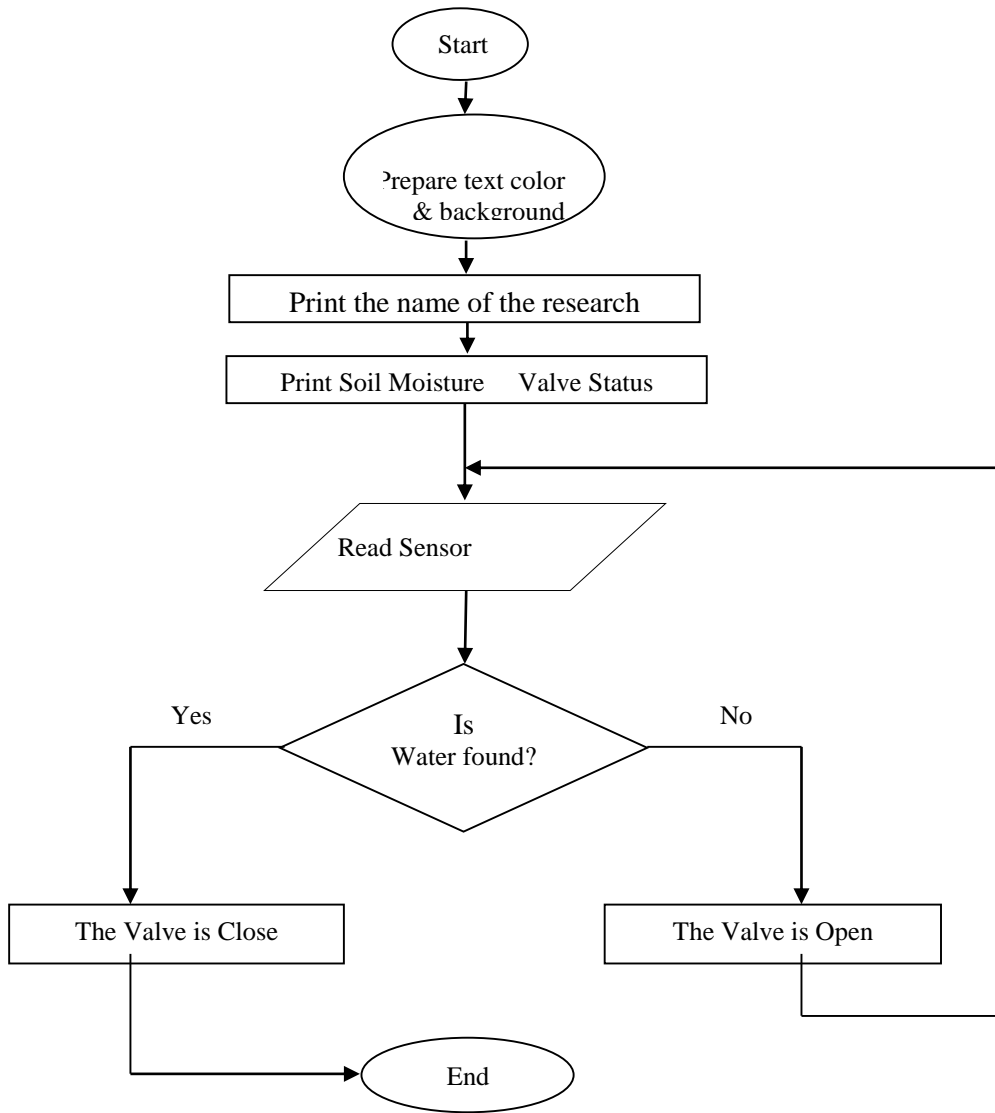


Fig. 5. Flow chart of the program Cycle

Code Analysis

Pre-processing:

- The including of files and functions which is needed by the program.
- The defining of the addresses of DATA, STATUS and CONTROL registers that are used by LPT1 parallel port.

The beginning of the program:

- The recognition of the integer variable which called sensor for the reading of the port.
- Clear totally the screen, the preparation of the text mode and the determination of the text color and background.
- Display the title of the research and the rest titles which show the status of the program by using the function "cprintf" after the function "gotoxy" to format the text (row, column).

The check of the sensor:

- Let the user to exit from the program by pressing any key on the keyboard.
- Read the STATUS register and to store it in the variable sensor and test the bit7 in the STATUS register which is bin 11 in the LPT (BUSY) if:
 - Its value equal 1 then go to subroutine (go to open valve) and execute it, so displays water found YES and valve status CLOSE.
 - Its value equal 0 then displays water found NO and valve status OPEN.

In the two cases then return to the beginning which is the check of the sensor.

Fig. 6 and Fig. 7 represent the screen of monitoring the soil moisture control system.

Those Fig.s show the water found (YES) status of the sensor and valve status (CLOSE) and the water not found (NO) status of the sensor and valve status (OPEN) and Fig. 8 shows the way of the installation of the whole system.

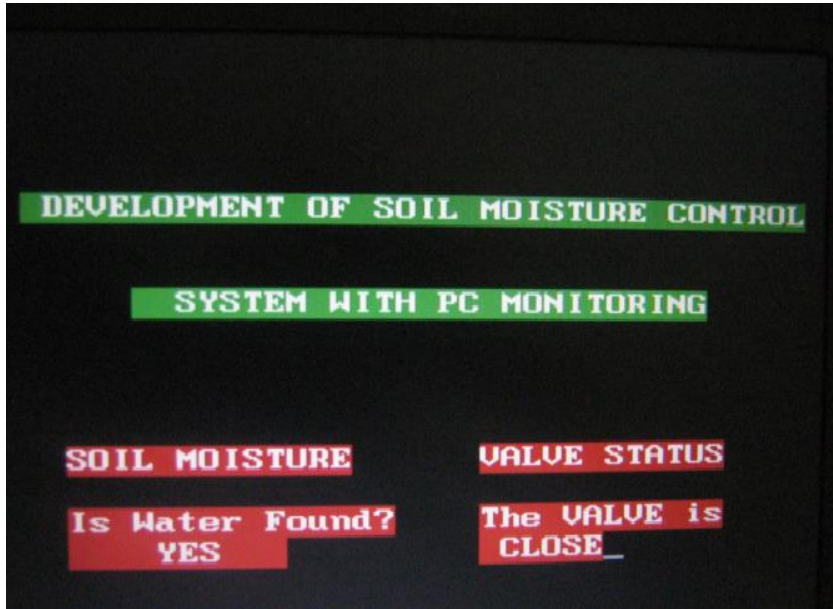


Fig. 6. Status “YES/CLOSE” of the sensor and valve respectively

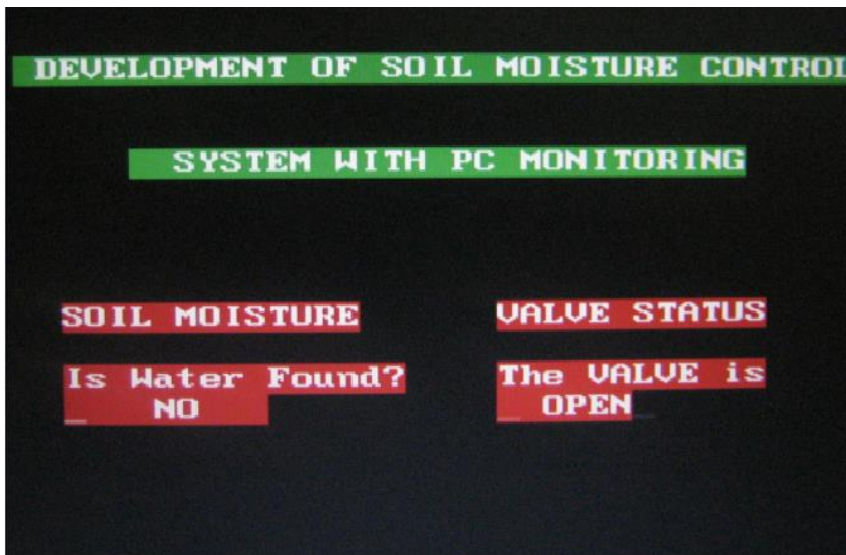


Fig. 7. Status “NO/OPEN” of the sensor and valve respectively

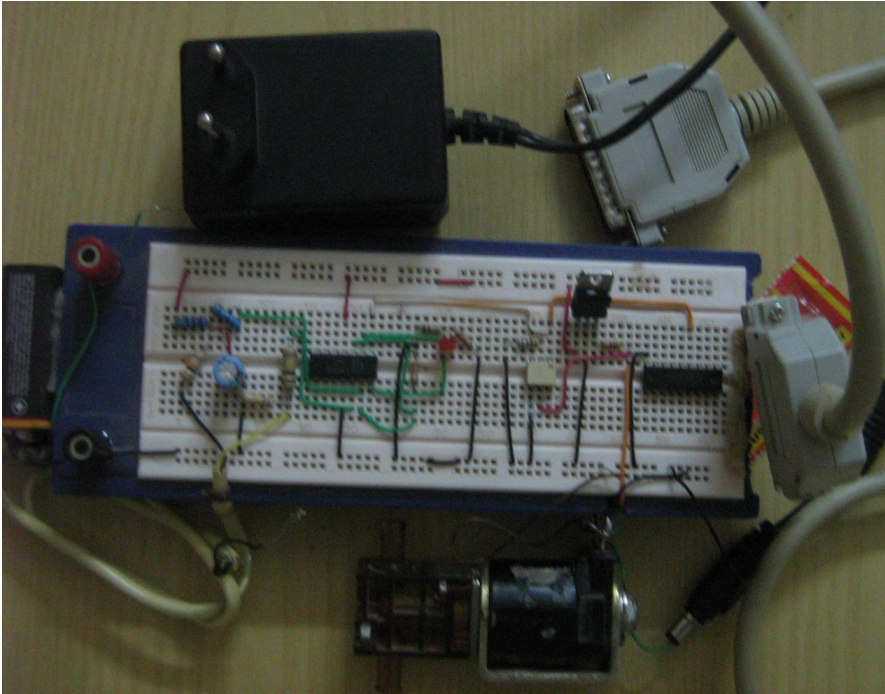


Fig. 8. Installation of the design system

CONCLUSION

In many micro irrigation systems, a controller is an important and integral part of the irrigation system. Controllers can help to achieve labor savings in addition to applying water in the adequate quantity and at the right time which enables the user to achieve high efficiency in water, energy and chemical uses. Irrigation controllers have been available for many years in the form of mechanical and electromechanically irrigation timers. These devices have evolved into complex computer-based systems that allow accurate control of water, energy and chemicals while responding to environmental changes and crop demands.

RECOMMENDATIONS

The researcher strongly recommends the use of the sensor ULN2429 IC to calibrate the design circuit's results with set points of data stored in a computer. This is considered to be more advanced moisture and liquid level detector. The choice of a proper program should be carefully considered.

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تطوير نظام التحكم في ماء التربة بمراقبة الحاسوب

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الملخص

هدفت الدراسة إلي تطوير تحكم في تدفقات مياه نظام ري يحتوي علي العديد من القنوات المرتبطة بحاسب رئيسي يقوم بمراقبة تدفق المياه لمنطقة جافة نوعا ما من التربة كلما تدنت كمية ماء التربة عن مستوي معين (threshold). عند تدني كمية الماء في التربة عن المستوي المعين، يتم فتح صمام الماء خلال فترة معينة حتى تُروى التربة، فيصل مستوي الماء إلي الكمية المعينة وعندها يتم إغلاق الصمام. يُربط صمام التحكم علي مخرج خزان الماء وعندما تتم تغذية الصمام بالتيار الكهربائي يتدفق الماء عبره ويصل إلي التربة. وعند قطع التيار عن الصمام، يغلق هذا الصمام ويتوقف ضخ الماء للتربة. وتم تصميم برنامج علي الحاسب الآلي يقوم بمراقبة مجس الماء وكذلك صمام الماء