WSN Based System for Irrigation and Fertigation Control in Horticulture for Semi Arid Regions

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***Abstract*— Water plays a crucial role in photosynthesis and plant nutrition and fertilizers maintain the health of the soil.Water management is a major concern in agriculture. In the semi-arid areas with limited irrigation facilities, it is observed that farmers have to bear huge financial loss because of wrong prediction of weather and incorrect irrigation methods. The real need is to improve the efficiency of irrigation systems and make effective use of water available, the focus is to develop an intelligent irrigation system which will enable irrigation to optimize the use of water and only irrigate where and when required. The main objective of the work is to develop a system for monitoring and controlling crucial parameters of soil such as soil humidity and fertility during development of horticulture crops. A system uses Wireless Sensor Networks to monitor soil moisture and its fertility. This system will ensure efficient automatic real time monitoring of the specific parameters to increase yield manifold and also save significant amount water and provide precise dose of fertilizer. This paper describes the overall architecture of the system with interfacing sensor node using Zigbee protocol and monitor the data from the Control station This work is specific to the areas having semi arid environment and moderate irrigation facility.**

***Keywords*— WSN; Zigbee; PSoC; irrigation, fertigation**

I. INTRODUCTION

This paper presents a view on use of WSNs in horticulture particularly in semi arid regions having ample potential to host horticulture but with irregular and/or low irrigation facility aiming to control irrigation and fertigation and create an opportunity to increase yield and save water. India is a land blessed with different agricultural zones depending on Climatic conditions of that area. Some of the agro packets are highly favorable to grow large number of horticulture crops. Presently horticulture crops occupy more than 12 percent of India's gross cropped area. Maharashtra makes a significant contribution in production of fruits at national level. Certain areas in Maharashtra such as Marathwada and parts of Vidharbha have large areas which come under semi arid zone or have less irrigation facility, but still have a capacity to breed fruits such as Pomegranate Mangoes, sweet lime etc. Implementing automation and sophistication in crop management in these areas will definitely help in high yield as well as make optimum use of water available for irrigation.

II. CONVENTIONAL METHODS

Traditionally farmers have been using historical data, qualitative measurements of the status of the crop, weather conditions and nature of the soil to decide the irrigation time and amount. This generally included using traditional information about irrigation, observation of plant physical appearance such as wilt and colour, surrounding climate (hot or dry) rainfall and appearance of soil. In traditional irrigation, the 'control system' is the farmer who controls the irrigation amount; 'actuation' is the action of adjusting the irrigation volume and/or timing; and 'application' is the resulting physical amount and timing of water and fertiliser applied to the crop. [1] Later on automatic control systems in the form of Microprocessor and Microcontroller based systems were used for spatially varied irrigation with the help of historical data rather than real-time data. Further sensor based irrigation systems were used which are more accurate than previous systems due to the real-time nature of the data. Sensor-based control systems are used to configure irrigation schedule and check for irrigation amounts. The duration of the irrigation event is either a fixed period of time or a calculated period of time corresponding to the crop's needs as indicated by the sensor data. The major drawback of this system was cost in laying down the network of sensors and wiring them to a controller which would create complexity when repositioning of the sensors needed. [1]

III. CURRENT METHODS

With the advent of wireless sensor networks irrigation control is flooded with use of Wireless sensor networks, in this systems wireless nodes are used for monitoring soil moisture which have effectively reduced time and efforts. This has been supplemented with immediate and quality decision making at the farm level, which can result in enhancing horticultural productivity and Quality. Block diagram of wireless sensor node is depicted in *figure 1*. Wireless sensor networks (WSN) is a network of small sensing devices known as sensor nodes or motes, arranged in a distributed manner, which collaborate with each other to gather, process and communicate over wireless channel about some physical phenomena. [11]

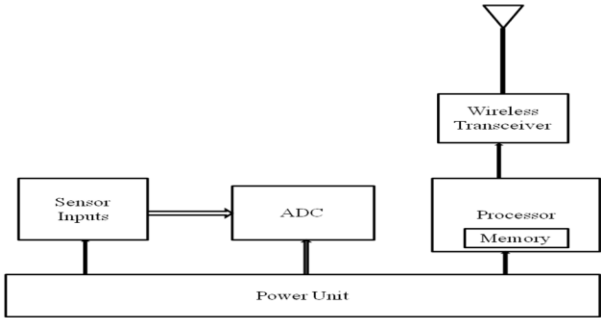

Figure:1 Depiction of wireless sensor node

The sensor motes are typically low-cost, low power, small devices equipped with limited sensing, data processing and wireless communication capabilities with power supply. A wireless sensor is a self-powered computing unit usually containing a processing unit, a trans-receiver and both analog and digital interfaces, to which a variety of sensing units can be connected. The sensor nodes communicate with each other in order to exchange and process the information collected by their sensing units.

WSNs can be used for Monitoring Physical and environmental Parameters including soil moisture, temperature, pH, leaf temperature, relative Humidity, air temperature. WSNs allow placement in critical locations without the need to put personnel in hazardous situations. Monitoring systems ensures quick response times to adverse factors and conditions, better quality control and a lower labour cost. One particular reason is that the sensor location can often require being repositioned and a traditional wire layout could cost a substantial deal of time and energy in order to address such wiring problems. The system aims to reduce the cost and effort of incorporating wiring and to enhance the flexibility and mobility of the selected sensing points. The wireless sensor network looks at being a comparatively self-organizing system. It allows sensor nodes to connect to the network and have their data logged to the allocated sensor server selected. The present article describes the development of a PSoC based crop monitoring system for water and fertilizer conservation using WSNs.

IV. SYSTEM DESCRIPTION

A Block diagram of PSoC based irrigation and fertigation control system using wireless sensor networks is shown in *figure 2*. The system consists of a soil moisture sensor and tempreture sensor to monitor soil moisture and Tempreture respectively. Soil nutrient content will be provided to system from database in timely based manner. PSoC CYHP28452 provides adaptable, flexible design platform for more efficient design. PSoC along with its modules is configured to acquire data from the sensors and through ZigBee module CC1100 data is transmitted to control unit. The data will be collected in time based manner which will be transmitted to the control unit through receiver in the form of packets. The control unit consists of relay unit which is used to control the motor used to control flow of water. The data in packets will be compared with standard values set in the system for that particular crop

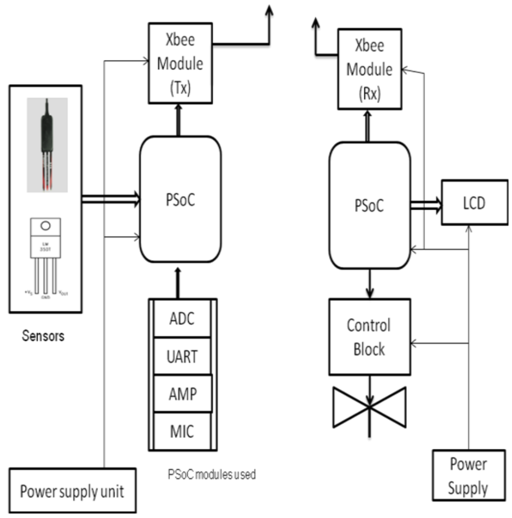

Figure 2: Block diagram of irrigation control system

and accordingly further action is performed. The output of the system will be commands to fertilizer tank, irrigation facility.

A. SELECTING A SOIL MOISTURE SENSORS

The first daunting task is to select a soil moisture sensor as we are aware that Water status of the soil can be determined by soil sampling (direct method) and soil moisture sensing (Indirect method). Direct methods of monitoring soil moisture are not very frequently used for irrigation scheduling, because they carry drawbacks such as it is labour intensive and cannot provide immediate feedback, also it is not an intrusive method. Soil moisture probes can be permanently installed at selected areas in an agricultural field to provide continuous moisture readings over time, which can be used for irrigation management. Various indirect methods are available for monitoring soil water content. Use of these methods depends on its cost, accuracy, response time, installation, maintenance and durability.A soil moisture sensor is a significant part of the system being developed as most of the signals interpreted through the sensors are going to be deciding factors for control of irrigation and fertigation. Many sensors were studied for this purpose, few of which are briefed here. The BJT based soil moisture sensor which works on change in conductivity of soil as water & fertilizer is added to it. Soil conductivity depends on the moisture content around the probes.[3] The other techniques which can be used to measure the soil moisture content include capacitance and heat pulse technique to determine the soil water content. In this design, the sensor uses the capacitance technique as the primary method and heat pulse readings for calibration and fault detection purposes. The main downside of this sensor design is that the heater requires a considerable amount of power.

Tensiometer measures the water potential of the soil and converts the readings into soil moisture concentration. The main disadvantage of this meter is that at lower soil moisture levels, the meter becomes unstable and difficult to operate. Moreover after a long operation time, plant roots could disturb the meter readings. Therefore ongoing maintenance is required around the meter probes. Two capacitor plates can also be used to measure the dielectric constant of the soil. The Colpitts LC resonance circuit is used to measure the soil moisture level.When the capacitance increases at the soil electrodes, the frequency of the oscillator shifts. The frequency counter is used to record the frequency shift. A fringing electric field capacitance based soil moisture sensor can also be used. The sensor can be visualized as a parallel plate capacitor, whose electrode opens up to provide a one sided access to the material (soil) under test. The main weakness of this design is the capacitive probe was designed on Printed Circuit Board (PCB) material, and once the PCB is exposed to harsh environments, it starts tarnishing. Therefore its useful life will be very short. The other possible soil moisture monitoring technique is a bridge circuit. This circuit is easy to build, but the accuracy of the circuit is dependent of resolution of the Analog to Digital Converter (ADC). The other disadvantage is this design requires good earth signal isolation in order to achieve a reliable analog signal output. [2]

Many of the sensors using mentioned principles are commercially available in market but to compromise with the cost of these sensors, It was decided to use conductivity based sensor. Simple arrangement of sensor circuit also tempted us to use this sensor.

As shown in figure 3 above, soil moisture sensor is constructed using a transistor as an amplifier and two resistors one of which is variable pot used to vary sensitivity of the sensor, and two probes .The soil probes is made up of consist of two copper wires which can be immersed into the soil under test. This arrangement gives a voltage output corresponding to the conductivity of the soil. The soil between the probes acts as a variable resistance whose value depends upon the moisture content in the soil. The resistance across the soil probes can vary from infinity for completely dry soil to very less resistance for 100% moisture in soil. Figure 4, shows the output is roughly linear for water present in soil as the amount of 10ml and above. The steep rise in the initial phase shows rapid change in soil resistivity as it absorbs water. [3] Curve 1 in figure 5 shows the sensor voltage output variation with no fertilizer added to the soil sample. Curve 2 and 3 depicts the sensor output variation when potash and urea fertilizers respectively, were added. Region A clearly shows the 'water absorption property' of the fertilizers. When initially, the soil is completely dry, all the three curves show 0.92V. Then Curve 1 rises suddenly to a high value at water content of 2.5ml or moisture of 4.03% .

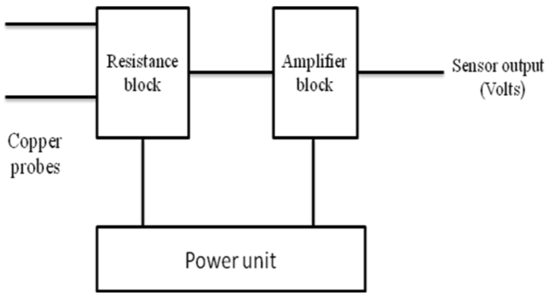

Figure 3 soil moisture sensor

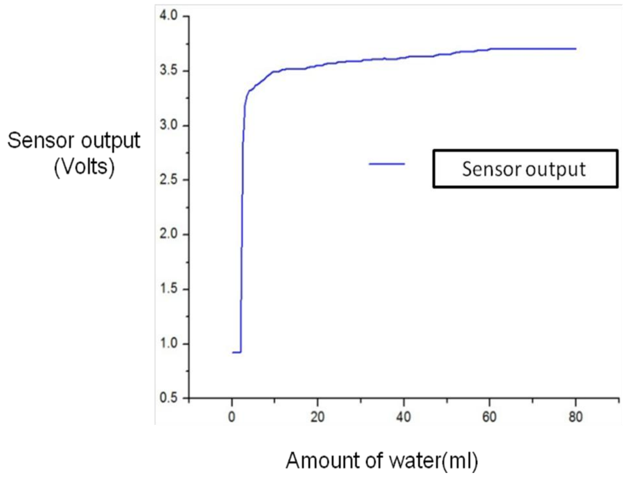

Figure 4: water addition to soil varies sensor output

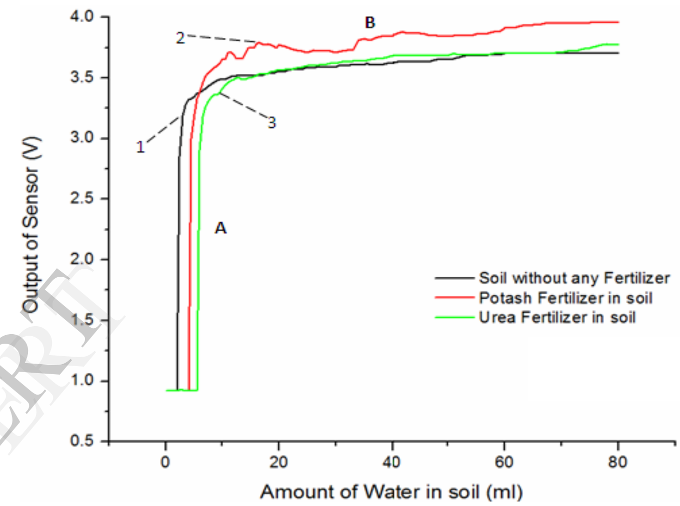

Figure: 5 Sensor output with addition of potash and urea with soil

Curve 2 rises at water content of 4.5ml or moisture of 7.26% . Curve 3 rises at 6ml or moisture of 9.68%. This indicates that potash fertilizer absorbs some amount of moisture when added to the soil. Similarly, urea also absorbs moisture more than that of potash fertilizer and hence shows more delay than the potash fertilizer in detecting moisture. This also shows water retention property of the soil.[3]

B. Frequency of Fertigation

The nutrients applied to soil by the fertilizers are not fully available to the plant due to leaching, runoff, and adsorption losses. Therefore a correction factor to compensate for these losses is to properly estimate need of fertilizer as required by the plant. Required amount of fertilizers can be estimated as follows.

$$F_n = R \times F_{cf} \qquad (1)$$

Where, F_n is the nutrient requirement, kg/ha;
R, recommended dose of fertilizer for the crop, kg/ha; and
F_{cf} is the fertilization correction factor.

Fertilizers can be injected into the irrigation system at various frequencies such as once a day, on alternate days or even once a week. This frequency depends on irrigation scheduling, soil type, nutrients requirement of crop and the farmers preference.[4]

C. Tempreture Sensor

Tempreture plays a very vital role in development of a crop plant. The process under which any plant undergoes during development are germination, sprouting, flowering and fruit development, for all this developmental processes of plant tempreture of the soil plays a very crucial role. Secondly transpiration rate is also governed by tempreture. Tempreture can also be indicator of relative humidity and soil moisture. In this system we are using LM35. It is precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. LM35 has an advantage over linear temperature sensors calibrated in ° Kelvin. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. The LM35 has low output impedance, linear output, and is inherently precisely calibrated make interfacing to readout or control circuitry simple.[5]

D. Transceiver

The major advantage of using WSN is to reduce cable network complexity and its cost. There are many wireless communication technologies such as RFID, GSM/CDMA, Bluetooth, and Zigbee along with others. Both Zigbee and Bluetooth operate within the Industrial Scientific and Medical (ISM) band of 2.4 GHz. Also, this band is available for license free operation and has worldwide compatibility.[2] The system designed is used is Chipcon CC1100. The CC1100 is a low cost true single chip UHF transceiver designed for very low power wireless applications. The circuit is mainly devised for the ISM and SRD frequency bands at like that of 315, 433, 868 and 915 MHz, but can easily be programmed for operation at other frequencies in the 300-348 MHz, 400-464 MHz and 800-928 MHz bands. The main intention is low cost and low power consumption. The low power consumption is really appealing for the reason that sensors can be placed at remote location where battery is the solo option for power supply. To achieve low power consumption the Xbee protocol is made to operate at low data rates. Baseband modem which is highly configurable is integrated in the RF transceiver. The modem can be configured to supports various modulation formats with data rate up to 500 kbps. In this system CC1100 will be interfaced with PSoC with few additional passive components.[6] A typiacal application circuit for CC1100 for low frequency applications is shown in Figure 6. The CC1100 provides extensive hardware support for effective RF communications, such as packet handling, data buffering, burst transmissions, clear channel assessment,

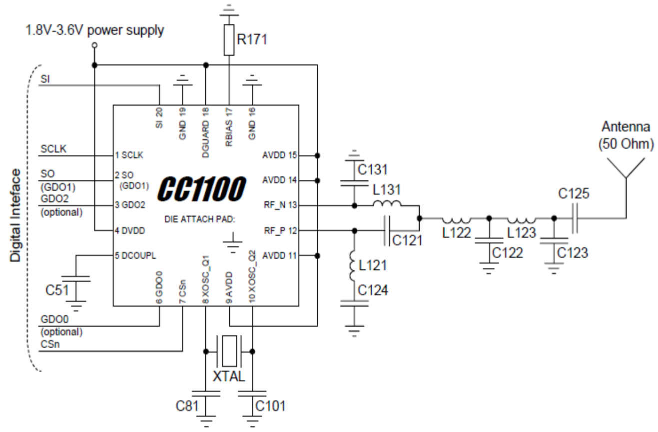

Figure: 6 Typical application circuit of CC1100 at 315/433 Mhz

link quality indication, and WOR. The main operating parameters and the 64-byte transmit and receive buffer FIFOs can be controlled SPI interface.

E. Programmable System on Chip(PSoC)

The PSoC family consists of many *Programmable System-on-Chip Controller* devices. These devices are designed to replace multiple traditional MCU-based system components with single, low cost programmable device. PSoC devices consists of configurable blocks of analog as well as digital logic along with interconnects which are programmable. This architecture of PSoC allows the creations of customized peripheral configurations to match the requirements of each individual application. Along with a fast CPU, Flash program memory, SRAM data memory, and configurable Inputs/Outputs are included in a range of convenient pin outs and packages. [7]

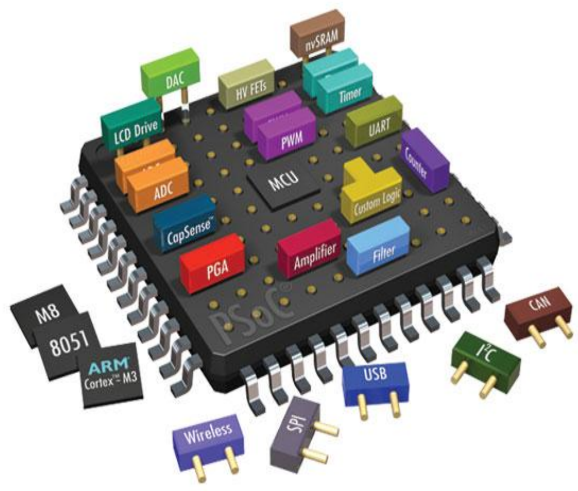

Figure:7 PSOC blocks

The PSoC architecture has four main areas: PSoC Core, Digital System, Analog System and System Resources. Configurable global bus arrangement allows all the device resources to be combined into a complete customised system. The PSoC CYHP28452 family can have up to 44 IO ports that connect to the global digital and analog interconnects, allowing access of 12 digital blocks and 12 analog blocks. Other system resources which can be used include devices such as I^2C, 04 decimators, digital clocks, and internal reference voltage, POR and LVD, SAR10 ADC.[7]

The system architecture proposed includes sensors placed in the field which is to be monitored for measuring moisture level of soil, Tempreture of the specific area. The system is build around PSoC. The use of PSoC introduces an easily adaptable, flexible design platform for more effective and efficient designs. Compared to other system a very Short time is required to develop the application around PSoC. Developed by Cypress PSoC is a configurable mixed signal array integrated a proven 8bit microcontroller. Figure 7 shows a PSoC family device developed by Cypress. PSoC has three separate memory spaces: SRAM for data, flash memory for instructions and fixed data, and I/O Registers for controlling and accessing the configurable logic blocks and functions.

F. PSoC Development Process

The development process of PSoC is different from the traditional microprocessors. The configurable resources inside enables a wide variety of user selected functions. A typical PSoC develop process is illustrated below in figure 8.

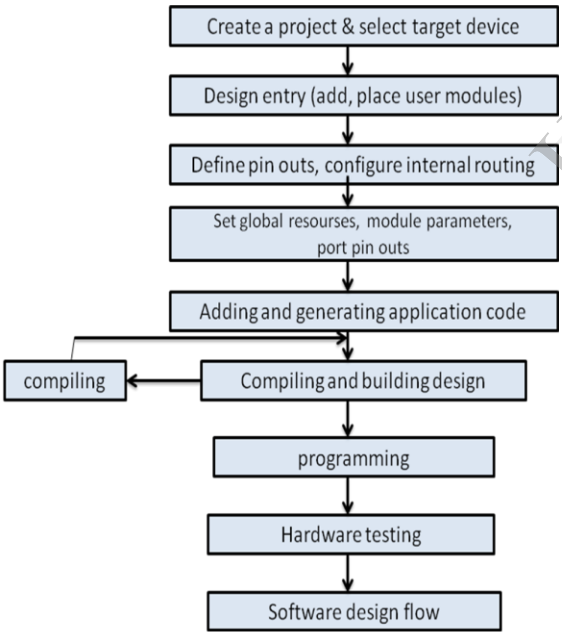

Figure: 8 PSoC Development Process

PSoC Designer provides a library of pre-built user modules. Each user module establishes the basic register settings that implement the selected function. After that a signal chain is built by interconnecting user modules to each other and IO pins. When users are ready to test the hardware configuration of the project, perform the "Generate Application" step. Then PSoC Designer generates source code that automatically configures the device and provides the software for the system.

G. PSoC software Details

PSoC Designer is the software interface for configuring and programming analog- and digital-peripheral functionality into a Cypress PSoC device. Inside the interface, you can select and place user modules, write C and/or Assembly source, and debug and program the project/part. When used with associated hardware, this dynamic hardware-software combination allows you to test the project in a hardware environment while viewing and debugging device activity in a software environment using ZigBee wireless standard. We come to the conclusion that using Programmable System on Chip (PSoC) has been the cost effective implementation used for wireless monitoring, acquiring and transmitting the signals for irrigation and fertigation control. The system successfully maintains the soil moisture level intact with the advantage of low-power consumption, which is crucial in such type of applications It has proved to be very useful for remote monitoring of soil parameters playing role in irrigation and fertigation.

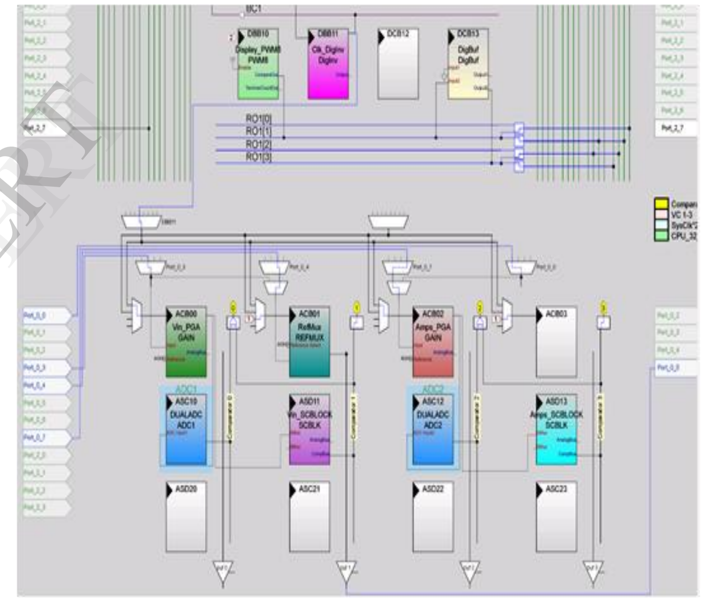

Figure 9: Analog and Digital blocks in PSoC.

CONCLUSIONS

This paper presents implementation and design of wireless sensor network for real-time soil moisture monitoring system by using ZigBee wireless standard. We come to the conclusion that using Programmable System on Chip (PSoC) has been the cost effective implementation used for wireless monitoring, acquiring and transmitting the signals for irrigation and fertigation control. The system successfully maintains the soil moisture level intact with the advantage of low-power consumption, which is crucial in such type of applications It has proved to be very useful for remote monitoring of soil parameters playing role in irrigation and fertigation. The use of a microcontroller as the building block of the system has integrated the facilities such as intelligence, compact size, and reliability. With the use of this highly integrated microcontroller, external components and wiring is reduced at large without compromising the quality and efficiency of the system. To wind up the conclusion we can see that the use of smart sensor system using intelligence of PSoC efficiently used for controlling irrigation as well as fertilizer.

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