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FPGA based Smart Water Distribution System using Wireless Sensor Network

Priyanka J. Ranade[1], Prof. S. B. Takale[2]

Department of ECE, Sinhgad College of Engineering, Vadgaon (BK), Pune, India [1,2]

Abstract: In Agriculture, water scarcity in field is one of the major problems for farmers since it affect the yield. To get rid of this problem proper distribution of water in field is required. The proposed work aims to develop a system to sense and monitor real time agricultural environment using wireless sensor network that is smart water distribution system. This is realized by network of FPGA based wireless sensor unit called field module which will be spread across the field to cover area under irrigation. The field module detects the soil moisture and communicates these parameters to FPGA based control unit having motor interfacing so that motor action can be controlled automatically. The information transferring between two modules is through ZigBee. Thus the proposed work provides an automatic controlling of irrigation system for proper management of water and labor cuttings.

Keywords: WSN; ZigBee; FPGA; Irrigation

I. INTRODUCTION

The birth of agriculture and domestication of plant was developed 10,000 year ago. Now agriculture play an important role in development of human civilization. But we can see nowadays agricultural field suffer from different climatic condition such as drought, flood, etc. it cause loss in agricultural production. That is in drought due to runoff of rainfall, under-irrigated areas are subjected to water scarcity, results in production loss to avoid such loss efficient water management in all climatic condition is required. Thus well designed water distribution system is required for profitable and environmental friendly irrigation. This system distributes the water in irrigation field in smart way that is water is provided only those places where it is needed and in required quantity so that water scarcity problem will resolve.

Wireless sensor based irrigation system is much simpler and low cost solution for optimized water management hence called smart water distribution system. In WSN based irrigation system numbers of sensor devices are installed in appropriate area of field. Wireless sensor network (WSN) consist of such several sensor components called 'nodes' as shown in Fig. 1.This nodes are use for acquisition of required environmental data. Agriculture domain poses several requirements that are following:

- Collection of soil information
- Monitoring of distributed land
- Different water requirements to piece of uneven land
- Diverse requirement of crops for different weather and soil condition

To fulfil above requirements smart sensor based monitoring system for agriculture have been used to increase yield of field. Where FPGA is used as controlling unit having facility of re-programmability and Re-configurability according to different environmental conditions. In proposed system Spartan3A FPGA board is use as controlling unit in both field module having sensor interfacing and control module having motor interfacing, This board has inbuilt analog to digital converter (ADC) and digital to analog converter (DAC).ADC directly interfaced to the sensors which have analog values. Soil moisture sensor is used to measure the moisture in agriculture land.

LCD used to display the moisture in soil. DAC interfaced to motor whose speed is controlled according to sensor data from field module. The Spartan 3A provides system to sense and monitor real time agricultural environment. It has two RS232 serial port having UART serial communication which allows us to design ZigBee network to established communication between field and control module.

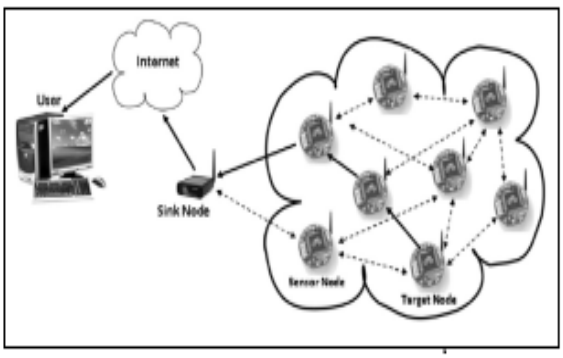

Fig. 1 Wireless Sensor Network [7]

The remaining paper present as, Section II give detailed literature survey on this topic, Advantage of FPGA in WSN is described in section III. Section IV gives comparison between different communication technologies, further in section V complete hardware system architecture including interfacing of ADC, DAC, Sensor and required software are explored. At last section VI presents all results and conclusions.

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II. LITERATURE REVIEW

After the research on climatic conditions, researchers found that due to unpredictable climatic conditions and mismanagement of water, agricultural field get suffered and the yield of agriculture and its quality goes on decreasing day by day. Hence the use of technology in the field of agriculture plays an important role in increasing the production as well as in reducing the water scarcity related problems. Some of the researchers tried for betterment of farmers and proper management of water in irrigation provides the systems that use technologies which are helpful for increasing the agricultural yield. Some of such researches carried out in the field of agriculture are summarized below.

An automation system having a low cost equipment and feedback type controller for site-specific management of irrigation systems and also to have an alternative power source like solar power or wind power. The data available from the various sensors will be received at the wireless base station for proper control, based on data [4]. The basic concept of WSN with its characteristics and application is explained [9] and its need in agricultural environment to monitor the agriculture environment [7]. Where real time data of climatologically and other environmental properties are sensed and control decisions are taken based on it, to modify them.

The architecture of a WSN system comprises of a set of sensor nodes and a base station that communicate with each other and collect local information to make inclusive decisions about the physical environment [1]. Accordingly WSN based system is developed using ZigBee network.[5] where agriculture monitoring is designed using ARM7 based 16/32-bit Microcontroller which measures the humidity, temperature and content of soil moisture and the measured parameters are displayed on a 16x2 LCD, the obtained parameters are transmitted using a ZigBee module. Some are develop the system is designed in XILINX-6-series FPGA using VHDL.[2] The objectives of the proposed system is to develop a low cost wireless controlled irrigation system, to observe water satisfied of soil in real time, to remove the need for workmanship for monitoring irrigation.

III. CURRENT CAPABILITIES OF FPGA

As discussed in above section most of existing WSN based irrigation control system developed on platform of micro controller whereas in proposed work smart water distribution system is developed on FPGA platform to make system more reliable than existing one. Capabilities of FPGA over controller are discuss below:

FPGA doesn't have a fixed hardware structure; on the contrary it is programmable according to user applications. Although logic cells are fixed in FPGA, functions they perform and the interconnections between them are determined by the user. So operations that FPGAs can do are not predefined. You can have the processes done according to the written HDL code "in parallel" which means simultaneously. However controller has a fixed hardware structure. It means that all the transistors memory, peripheral structures and the connections are constant. It makes system robust and more flexible than controller based system.

FPGA gives real time controlling unit with fast processing speed than controller since FPGA has ability of parallel processing and it make it superior in many areas. Since the user can determine the hardware structure of FPGAs, we can program FPGA to process larger data with few clock cycles.

Whereas this is not possible with the controller. Because data flow is limited by processor bus (16-bit, 32 bit, etc.) and the processing speed. Thus it possible to define and use processor and user-specific hardware functions on only one chip by using FPGA with high performance.

IV. COMMUNICATION TECHNOLOGY FOR WSN

Today, due to development of radio frequency wireless technologies, expensive wiring get reduced or eliminated. Whereas the system based on intelligent sensor are currently expands in their function and performances of intelligence: transmitting and receiving data in real time with low power consumption hence it requires communication technology accordingly. Various communication technologies have emerged and provide communication differently.

The comparison of this technologies based on its constraint is given in Table I.

In our system we required low power and low cost system with effective coverage and expendability thus ZigBee is considered for networking system in smart water distribution system. Whereas through Wi-Fi we can increase the range and data rate but simultaneously cost and power usage increases on other hand Bluetooth is cheapest one but it can only use in small networks since it provide low range and low data rate communication. Hence ZigBee is most suitable technology for long range and low power and cost effective network.

TABLE I.
COMPARISON BETWEEN WI-FI, ZIGBEE AND BLUETOOTH [5]

Features	Wi-Fi	Bluetooth	ZigBee
Frequency band	2.4GHz	2.4GHz	2.4GHz
Data rate	>11Mbps	1Mbps	250kbps
Range(m)	100	10	70
Power consumption	High	Medium	Low
Battery life	Hours	1 week	>1 Year
cost	High	Low	Low
Complexity	Complex	Very complex	Simple

V. HARDWARE SYSTEM ARCHITECTURE

In this section, complete hardware structure of FPGA based smart water distribution system is described. The block diagram of system is as shown in Fig. 2

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A. Interfacing ADC and DAC to FPGA

The analog to digital converter (ADC) and digital to analog converter (DAC) is inbuilt in Spartan 3A FPGA board. The Spartan 3A include MCP3004 device having 10 bit resolution for analog to digital conversion. It is programmable to provide two pseudo-differential input pairs or four single ended inputs channel. One channel among 4 is used to take analog data from soil moisture sensor. This analog value from sensor is converted to 10 bit digital equivalent. Communication with device is accomplished using a simple serial interface compatible with the SPI protocol.

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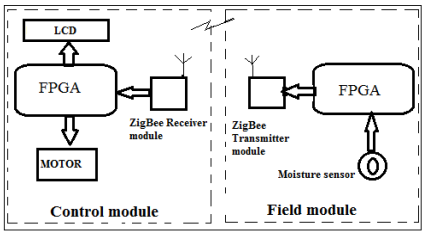

Fig.2. Block diagram of proposed system

The Spartan 3A also includes DAC084S085 device having general purpose QUAD 8-bit voltage-output ,digital-to-analog converter(DAC) that can operate from a single +2.7v to 5.5v supply. In control module sensor data received from field module is in digital format hence DAC is required to provide equivalent analog voltage for controlling motor action.

B. Interfacing moisture sensor to FPGA

In sensor based smart water distribution system first we have to monitor moisture contents of agricultural field. Hence moisture sensor FC-28 is implemented in a field along with FPGA based processor. The pin diagram of FC-28 Moisture sensor is shown in Fig. 3. It is mainly used to detect the presence of moisture in the soil. It gives an output in two different formats i.e. analog as well as in digital. In digital mode sensor reads the value and compare it with threshold value which is set through comparator circuit of FC-28,if sensor value exceeds the threshold value then it gives 0V digital output to Spartan 3A otherwise high output voltage of 3.4V is generated i.e. logic '1' to Spartan 3A board. In Analog mode accurate moisture of soil can be determined. Hence for proposed system in order to get the exact percentage value of moisture sensor is activated in analog mode. The data pin of sensor is connected to channel 4 of inbuilt ADC

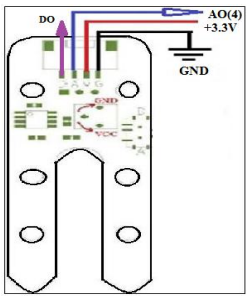

Fig.3. Pin diagram of soil moisture sensor (FC-28)[5]

C. Interfacing LCD to FPGA

A liquid crystal display (LCD) is a thin, flat panel used for electronically displaying information such as text and integers. The Spartan 3A board have inbuilt 16x2 LCD display interfaced with FPGA. The pin connection to FPGA is as shown in Fig. 4. Eight data lines are used send data on the LCD. When RS=0 and EN pin is made high to low, command is send to LCD. When RS=1 and EN pin is made high to low, data is send to LCD.

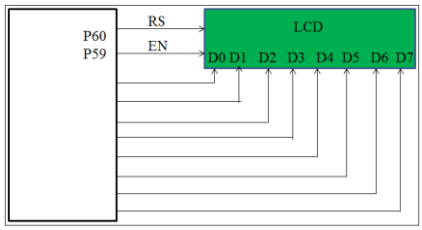

Fig. 4. Pin connection diagram of LCD to Spartan 3A

The sensor values are continuously displayed on LCD in the form of percent value of moisture in soil.

D. Interfacing Motor to FPGA

In proposed system, control module having Motor interfacing with FPGA as shown in Fig. 2.Where switch ON/OFF action and speed controlling of motor is automatic and based on moisture in soil sensed by sensor in field module. So that water should provide to only those field where it is needed and in required quantity. Since proposed system aims to water conservation and proper distribution of water in agricultural field. The flow diagram of motor action is given in Fig. 5

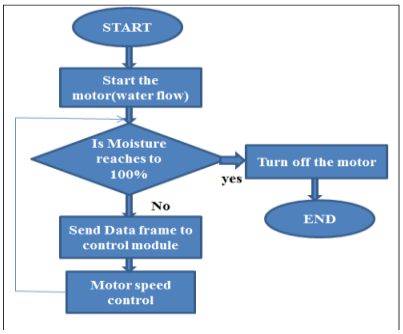

Fig. 5. Flow chart for motor control

Motor action required analog voltage from FPGA, but data received from field module is in digital form hence inbuilt DAC is required to convert digital output from FPGA to analog voltage. Thus voltage pin of motor connect with 1st channel among 4 channel of inbuilt DAC.

E. Interfacing ZigBee to FPGA

ZigBee is wireless communication protocol for low power, low rate, reliable and secured wireless personal area network. Hence in proposed system ZigBee is used to established communication between field module and control module. Before establishing network ZigBee modules are first configured using X-CTU software. To interface ZigBee module with Spartan 3A. ZigBee

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modules are mounted on ZigBee development kit contain RS-232 board and serial port having TX,RX pin for serial transmission and reception respectively. This will connect to RX ,TX pins of RS232 port on Spartan 3A kit so that serial data transmitted through TX of Spartan 3A board is received by ZigBee through RX pin and vice versa.

VI. RESULTS

This section gives results of all interfacings which had carried out in proposed work.

A. FIELD MODULE

a) Sensor interfacing

In proposed work moisture sensor (FC-28) is use in its analog mode for getting accurate reading of moisture. Here as moisture in soil goes on increasing voltage on analog pin of sensor is get decreased. As shown in Fig.6

b) ADC Interfacing

In order to get accurate reading of moisture in soil, output of sensor taken from its analog pin(AO) but required input of FPGA is digital, Hence analog to digital converter is interfaced with FPGA, ADC convert analog voltage getting from sensor to its equivalent 10 bit digital value.

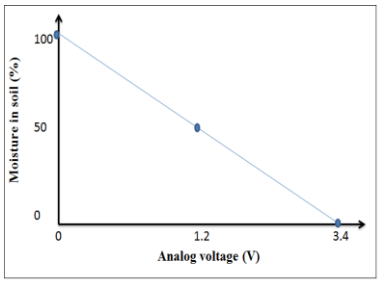

Fig. 6. Graph of Soil moisture % Vs Analog voltage

B. CONTROL MODULE

Motor interfacing:

Proposed system aims to proper distribution of water in agricultural field where it needed and in required quantity. Hence motor interfaced with FPGA in control module where motor action is automatic and depends on signal received from field mdule as shown in Fig.5. When field land is completely dry and motor get switch on then motor start distribution of water in full speed as moisture in soil goes on increasing the speed of motor start decreasing and as moisture reaches to 100% motor get automatically turned off.

a) ZigBee NETWORK

ZigBee module along with ZigBee development kit containing RS-232 and serial port is interfaced with both field module and control module, one play a role of transmitter and other is receiver respectively to established communication between two nodes of network wirelessly.

VII. CONCLUSION

This paper describes the methodologies of designing ‘Smart water distribution system’. This system will help in proper distribution of water in agricultural field where it is needed and in required quantity .This system is automatically controllable irrigation system where motor action is controlled based on wirelessly transferred data from sensor based field module. This paper also provide extensive details for the wireless communication interface of ZigBee to sensor based field module and control module .ZigBee wireless technology used in this paper offer low power and low cost system with effective coverage and expendability. Hence this paper proved a concept of promising low-cost wireless solution for in-field WSN and automatic control of irrigation. The use of FPGA elements in field module and control module facilitates the system for real time parallel processing unit and re-configuration according to different environmental conditions.

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