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VLSI Architecture for Smart and Precision Agriculture using Sensors

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ABSTRACT

World population has almost doubled during the last century increasing dramatically the need for food to support the population over 7 billion persons. Precision agriculture is a type of innovative agriculture, based on new technologies, which aims to streamline the agricultural process. Parameters such as temperature, humidity, soil characteristics, and nutrients all play a role in plant development. Numerous sensors are available to measure the environmental factors and depending on datum, the devices monitor and control the parameter changes for each crop. Some existing technologies are more complex and very complicated for farmers to implement. The main goal of this project is to produce precision agriculture-based grid with high performance and low energy consumption.

1. Introduction

In the past few years, all applications related to fields in modern technology have been developed like automation and the internet of things. In India, most of the population depends on agriculture (production and farming). Due to traditional farming, the crop was damaged causing loss to the farmer and thus precision farming was introduced based on the concept of automation [1]. The use of precision agricultural crop production will increase and reduce crop spoilage. In precision cultivation, all parameters responsible for plant growth can be monitored and vary according to the plant's growth needs.

It is important to measure and monitor many interacting physical variables in greenhouse crops in order to improve their quality and productivity. Only control systems with built-in applications are capable of completing these tasks. It is costly to build a greenhouse. The high cost of greenhouse technology prevents many farmers from adopting it. Greenhouse's approach to environmental control is the focus of our project. Via input sensors and procedures, with the greenhouse controller, changes in temperature (dry temperature, wet temperature) can be sensed and the necessary actions to be taken. Real-time monitoring offers accurate and timely crop and soil status information, which is crucial in making crop-production-improvement decisions [2]. Fig. 1 shows the comparison of traditional and precision agriculture.

In traditional agriculture, many problems arises like excess water, pesticides, temperature etc., Due to this inorganic farming occurs. Whereas, in precision agriculture, various sensors like P-mod HYGRO, DHT11, TMP3 and so on are used. By using the sensor data, input to the FPGA, one can able to control the various problems in agriculture field. Kavianand et al., proposed a smart drip irrigation system for sustainable agriculture. ARM9 processor is used for controlling and monitoring the irrigation system [3].

Fig. 1 Tradition Vs Precision Agriculture

Precision Agriculture (PA) was originally developed to address variability in soil and crop parameters for large-scale agriculture in developed countries. The general concepts of PA can also be adapted for farm-based agriculture for small and marginal farmers in Developing Countries. This approach is characterized by a farmer-soil-crop database acquired from the field, crop calendars provided by agricultural experts, real-time acquisition of parameters such as temperature and rainfall through sensors, and an analytical model that simulates the crop calendar using static, semi-static and dynamic inputs, leading to farmer- and crop-level support advisories delivered through devices such as mobile phones and tablets.

Sabo and Qaisar [5] uses IOT with an intelligent wireless sensors network in order to monitor the health of plants and to population of larva in a remote crop field. The sensors data is collected by the front end sensing node, developed with an ARM processor. Adetunji et al., developed a Cloud-based Monitoring System using arduino [6]. Measurement of variables is required to achieve the behavioural analysis according to the sensors used. The Sparkfun's soil moisture was used to collect volumetric water content of the soil. Humidity and ambient temperature were derived from DHT22 sensor, while the DS18S20 sensor was used to get reading for soil temperature. The DS18S20 is durable and could withstand moisture for a long period. Dew point was calculated from the readings of ambient temperature and humidity. In this we developed a cloud-based monitoring platform from scratch, starting from the Platform-as-a-Service Layer to monitor agricultural resource. The development involved a cost-free deployment when using arduino.

Dholu et al., brought the application of cloud based IOT in the precision agriculture [7]. The idea is to sense all the parameters like Soil moisture, Temperature & Relative humidity around plant and light intensity from the agriculture field and take decision based on the outputs and this is controlled with an android application which accesses all the required parameters so that all the parameters to be visualized with the smart phones.

Sudharsan et al., suggested Smart Agriculture Monitoring and Protection System Using IOT. In this the hardware and software comprise of sensors, Arduino (ATmega328 microcontroller), GSM and Wi-Fi module [8]. In this the sensors and the devices are connected to the Arduino which consist of ATmega328 microcontroller. Voltage output from the sensors sent as inputs into the Arduino. Based on the input values, Arduino output specifies voltage to turn ON/OFF the devices. The proposed system used for two purposes: one, for gardening purpose and another, for agriculture purpose. In this the heart of the project is Arduino Uno board. Whenever there is sufficient amount of water in the field, water will not pump into the field. Whenever, the water moisture level of the soil goes low, water will be pumped into the field until the required amount of moisture is required. DHT11 sensor measures the temperature and humidity value of the field. PIR motion sensor detects the motion of the intruder (human/animal) into the field. Thus, the sensor values are continuously monitored and the readings are displayed to the farmer's mobile via GSM sim900A module where a SIM card with 3G data pack is inserted into this modem which provides IOT features to the system.

Lakshmisudha et al., introduced a Smart Precision based Agriculture using Sensors [9]. The method used in this is by using Zigbee and raspberry pi, two different technologies that can be used to monitor agricultural factors in a reliable and efficient manner. Firstly, the soil moisture sensor detects the moisture content. If the level falls below allowable level, a notification is sent via user's mobile phone. In this case, the outputs are determined in the form of zeros and ones. If the output value is "0" which means that the sensor value is low when compared with the pre-defined threshold scale after that the motor or fan are to be turned on based on the sensor data. The user can then control the motor by using android application. The relay assists in switch on the motor, which causes water to flow out of tubes. Every one minute, the moisture sensor records the moisture values. An algorithm compares the level with the required value each and every period. When it reaches the required level, motor will be automatically shut down, and a notification of the same to sent on to user. If the temp is 1 then the relay will on the dc fan and if the temp is 0 then the dc fan will turn off.

Ranade et al., proposed a Smart Irrigation System using FPGA based Wireless Sensor Network where Spartan3A FPGA board, Moisture sensor, Zigbee and motor pump were used [10]. A sensor-based system (field module) is spread across an agricultural field. In this case, a moisture sensor is linked to an FPGA board in order to collect information of moisture content of the agricultural land. For exact percentage of moisture in soil they have taken analog output of moisture sensor and converted to digital using ADC convertor. This digital signal is given as input to the Spartan3A FPGA board. Based on the moisture value the motor is going to on. In this the zigbee which is the receiver device will receive the moisture value from the sensor field module and do evaluation for decision making and covert that into equivalent analog voltage to control the hardware motor pump. i.e., at the time of agriculture land in dry condition, motor gets started at the full speed and disperse water at the specified area in required quantity till the moisture content reach to hundred percentage and then motor will switch off automatically.

The aim of the proposed system is to develop an automated precision green monitoring system that will be crucially minimize the human efforts and also improves the yield and production quality. For the crops, this system will provide a greenhouse environment. The sensor data can be used to ensure that the crops get exactly what they need in terms of water content, temperature, and so on. This is implemented with Basys3 Artix-7 FPGA board with the software Vivado 2016.4 and Xilinx SDK. The goal of this proposed system is to produce a precision agriculture-based grid with high performance and low energy consumption.

This section gives the introduction and the related works. The remaining paper is organized as follows. Section II details the proposed methodology and the design flow, while Section III gives the results and discussions of the methodology and Section IV provides conclusions and some idea for future works.

2. Smart Precision Agriculture

To achieve low power consumption, two methods have designed using the digital temperature and humidity sensors (P-mod HYGRO and DHT11). With the help of Xilinx Vivado an IP Integrator using Micro blaze and P-mod HYGRO port has designed. Using these inbuilt .c code is generated in inbuilt drivers. This .c code is dumped into the Basys 3 Artix-7 FPGA Board by using SDK tool. Using the terminal emulator either tera term or serial output terminal or some hardware like LCD display, seven segment display so on.

Also, using DHT11 sensor, Verilog flow is designed and commands has given based on the threshold values of the particular crop. The code is dumped into Basys 3 Artix-7 FPGA Board with DHT11 sensor. Based on the sensor data the action need is displayed in the console window. The updates are notified by the farmer and the necessary actions to be taken further for the growth of plants. Fig 2 shows the block diagram of the proposed precision agriculture system.

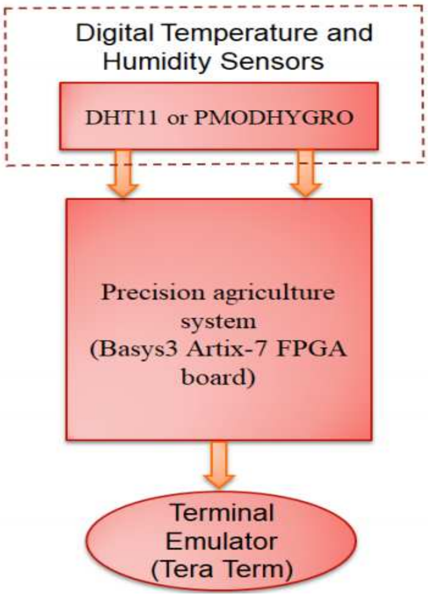

Fig. 2 Block diagram

The data sets to be collected from "The new seed starters" handbook by the University of California, agriculture and natural resources. Many environment and room factors influence seed germination. The condition of the seed, presence of water, sufficient air, temperature, light, soil conditions and organic matter. A great success will be achieved when optimum conditions are provided for the seed germination. The optimum soil temperatures and the finest humidity range is given in table. 1 for seed germination.

Table. 1 Temperature and humidity range for seed germination

S. No	Name	Temperature (C)	Humidity
1	Green leaves (Spinach)	24 - 30	50 - 60 %
2	Cabbage	15 - 30	50 - 60 %
3	Carrot	22 - 30	45 - 65 %
4	Cucumber	25 – 35	60 - 70%
5	Onion	18 – 30	50 - 60 %

The optimal temperature and humidity range is to be maintained for the growth of plants. A software and hardware tool is required to monitor and control the optimal temperature and humidity values. With the help of Basys3 Artix-7 FPGA Board, a system is developed by which the environmental parameters can be easily monitored and controlled by the farmers. For the seeds to germinate, the day and night optimum temperature is controlled by heater and cooler. The moisture value is controlled by giving proper water supply with the help of motor pump. The optimal temperature and humidity in plant is sensed by the digital temperature and humidity sensor (DHT11 or P-mod HYGRO). If the ranges are not in appropriate limit further controlling actions to be taken by the gadgets (heater, cooler, motor pump) by the farmer with the commands given by the software on PC through Basys3 Artix-7 FPGA Board.

2.1 Finite state machine design using DHT11 sensor

Fig. 3 describes the temperature and humidity control with DHT11 sensor using flow chart.

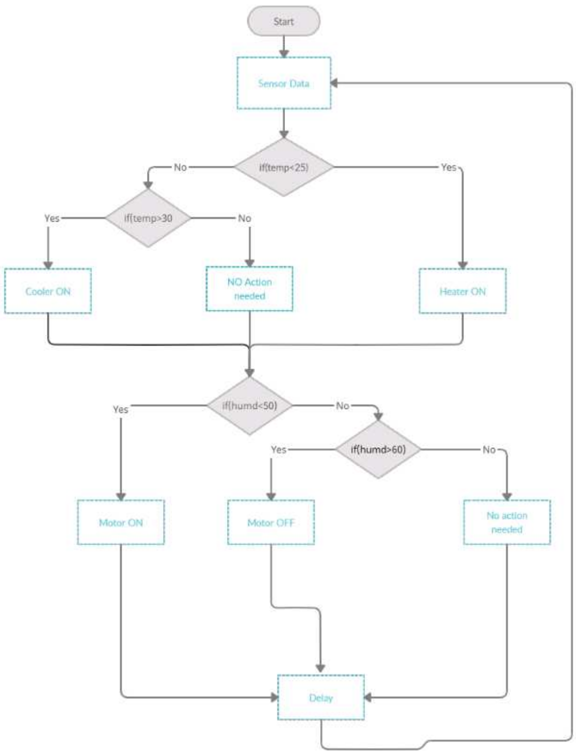

Fig. 3 Flow chart for temperature and humidity control

In this the sensor DHT11 sense the data of temperature and humidity. These sensed data is send to Basys 3 Artix-7 FPGA Board. The following steps are involved in the module design:

1. If temp < 25
   Then "Action needed: Turn ON heater"
   Else if temp>30
   Then "Action needed: Turn ON cooler"
   Else
   "No action needed"
2.
   If humd < 50
   Then "Action needed: Turn ON motor" Else if humd > 60
   Then "Action needed: Turn OFF motor" Else
   "No action needed"

This is simulated and synthesized using Vivado 2016.4 and the process repeats again and again gives continuous monitoring to the farm land. Based on the sensor data, the farmer controls the environmental parameters with the necessary hardware tools. As there is no need of ADC conversion by using DHT11 and P-mod HYGRO sensors, the time delay also low when compared with existing methods.

2.2 Design flow using P-mod HYGRO

The following steps describe the design flow of IP integrator using P-mod HYGRO with the software Vivado 2016.4 and the process works with Basys 3 Artix-7 FPGA Board.

STEP-1: Create a new block project in Vivado 2016.4 and a new block design is selected where micro blaze processor and sys clock is added.

STEP-2: From project settings, add Vivado library and add system clock → select P-mod-connector JA (P-mod HYGRO) and also select UART.

STEP-3: Do build automation and connection automation. Save the design, regenerate the layout and validate the design.

STEP-4: Select bin file and generate bit stream including the bit stream. Check the power consumption.

STEP-5: Export the project and from files select launch SDK. Open new application project

STEP-6: Create an application and select an empty application.

STEP-7: Copy the P-mod HYGRO .c from drivers and paste it in the created application. Save the application and select program FPGA.

STEP-8: Run the application, simulate and verify the output.

3. Results and Discussions

The proposed methodology is simulated and synthesized using Xilinx Vivado 2016.4 software tool in Verilog HDL. After synthesis, implementation is performed with Basys 3 Artix-7 FPGA Board and the output results (power consumption and bonded IOB's) of the two sensors are compared. By using PMOD sensors, the performance of the proposed system is greatly increased when compared with the earlier techniques.

3.1. Simulation results using P-mod HYGRO

Fig. 4 is the IP integrator window using micro blaze processor (micro blaze processor supports Basys 3 board) where the power consumption is to be calculated. The total on-chip power utilized using P-mod HYGRO is 0.212W.

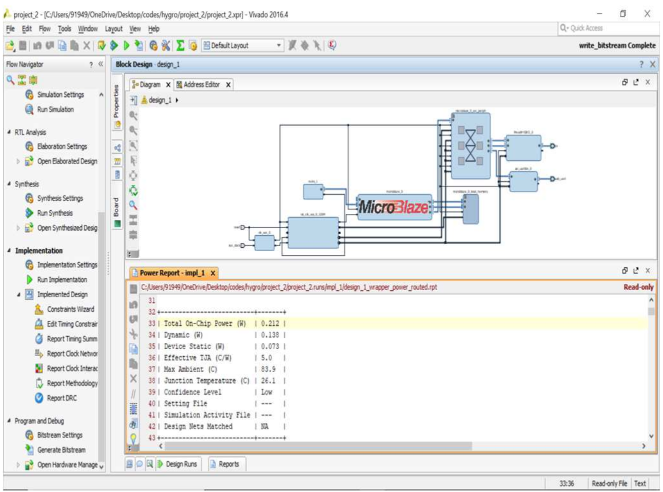

Fig. 4 IP Integrator and power consumption

Fig. 5 shows the .c file for P-mod HYGRO which has taken from in-built drivers using SDK tool. This file is dumped into Basys 3 Artix-7 FPGA Board and the output is verified using the Tera term terminal emulator. Fig. 6 gives the temperature and humidity data in Terminal emulator (Tera term).

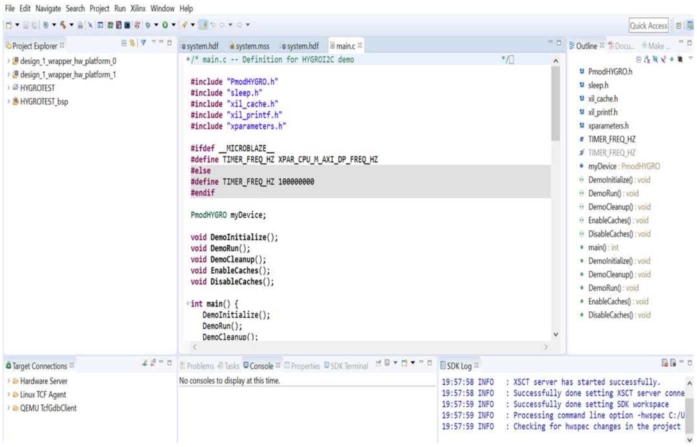

Fig. 5 P-mod HYGRO.c file

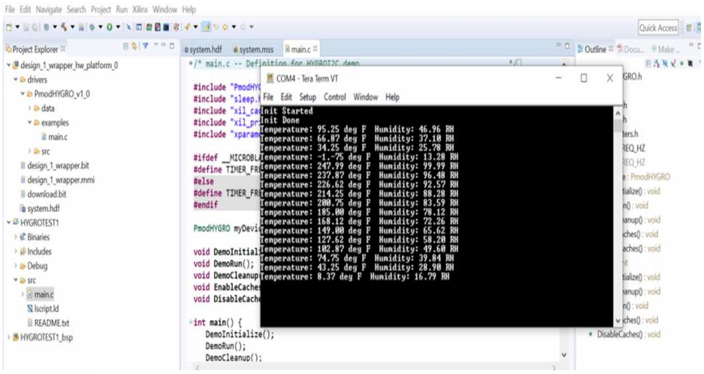

Fig. 6 Output in Tera-Term

3.2. Simulation results using DHT11 sensor

The simulation and synthesis is performed using the RTL design in the HDL software tool. Fig. 7 shows the waveform of the RTL design.

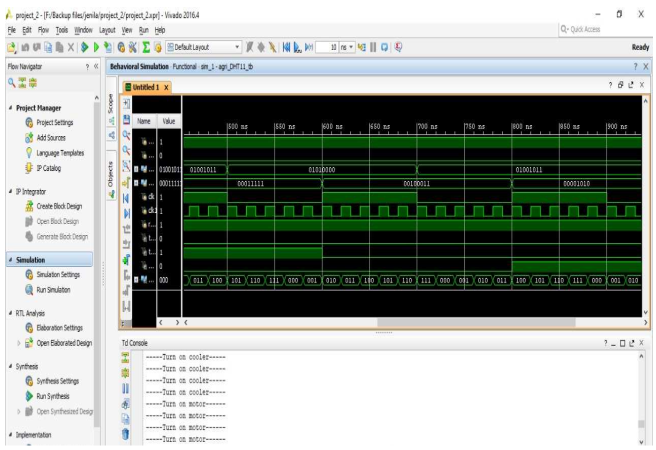

Fig. 7 Waveform of the RTL design

The necessary actions needed for the control of temperature and humidity is displayed in the Tc console window as shown in Fig. 7. After synthesis and implementation, the power consumption is calculated. The total on-chip power utilized using P-mod HYGRO is 4.926 W. Fig. 8 gives the implementation result where 67 nets and 48 leaf cells are used.

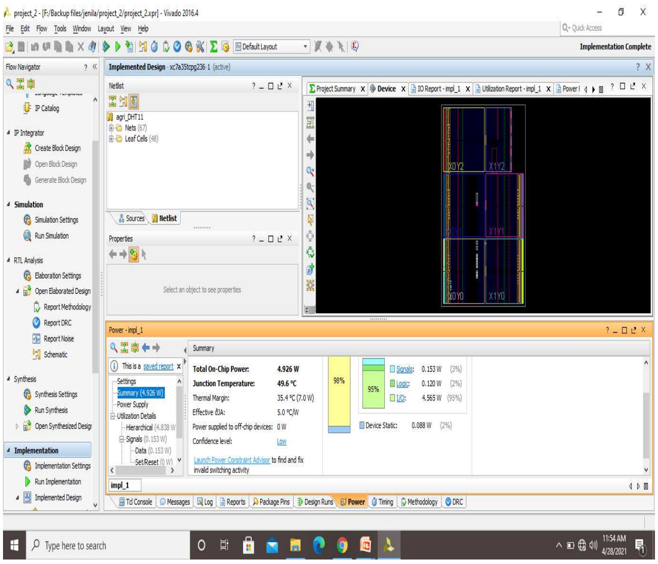

Fig. 8 Implementation result

The gate level schematic diagram of the RTL design is shown in Fig. 9, where 17 cells, 27 I/O ports, 43 nets and 19 leaf cells are used. This gives the elaborated design of the proposed system and the verification is done using automation processes by the software tool.

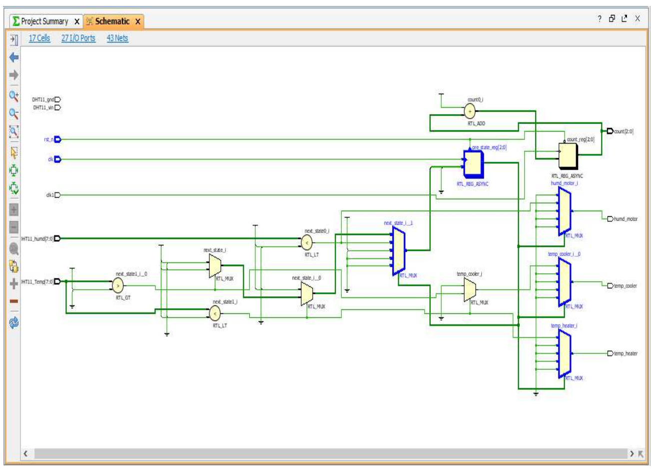

Fig. 9 Schematic diagram

In utilization report, one can able to find the slice LUTs, Logic Slice Registers, Bonded IOB's and so on. Fig. 10 gives the device utilization summary of the proposed precision agriculture system.

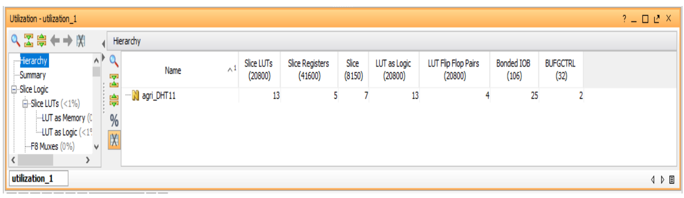

Fig. 10 Device utilization summary

Table. 2 shows the comparison result of the proposed system of both DHT11 and P-mod HYGRO sensors.

Table. 2 Comparison table

Sensors	Power Consumption	Bonded IOB's
P-mod HYGRO	**0.212W**	**12**
DHT11	**4.926W**	**25**

4. Conclusion

In this work, power utilization by the basys3 board using PMOD sensor and DHT11 sensor are compared. The power utilized by PMOD sensor is 0.212 W which is low compared to the DHT11 sensor. By using PMOD sensors, the performance of precision system also highly increased. As there is no need for ADC conversion, the time delay also less when compared with existing methods. Also, the power utilization also low in comparison with other earlier techniques. Further, this project to be implemented by considering other parameters like moisture and soil characteristics and to reduce the complexity of the precision agriculture system.

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