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Mixed Signal Based VLSI technology for Wireless Sensor Network

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***Abstract*- The miniaturization of an embedded system is new trend in instrument designing. For miniaturization of an embedded system the integrated circuits (ICs) technology plays vital role. Moreover recent IC technology provides analog as well as digital reconfigurable systems on a single chip are known as a Programmable System on Chip (PSoC). These devices are capable of analog as well as digital signal conversion and processing. Due to such features, these systems are widely used in various sectors like industry, scientific, medical, military, etc.**

The agricultural parameter monitoring is challenging field to the researchers. The monitoring and controlling of the agricultural parameters helps to enhance the quality and quantity of the product. Considering such factors it is proposed to design PSoC based Wireless Sensor Network (WSN) for agricultural parameter monitoring. For this, the sensor is equipped with PSoC for physical parameter monitoring and its output is connected to PGA of PSoC. The PSoC is used to process analog and digital signal. The processed data is calibrated in respective unit and displayed on LCD and same is transmitted towards base station through RF module, ZigBee. The smart ZigBee transceiver operates on IEEE 802.15.4 standard. Moreover, the base station of WSN is designed to demonstrate collected information in user friendly format.

Keywords: Mixed Signal, PSoC 1, ZigBee, VLSI technology, Relative Humidity

I. INTRODUCTION

The VLSI technology become standard in the field of electronic research and design, resulting in to highly promising field of design of programmable system on chip for dedicated applications [1]. During early days the field of VLSI design was constrained in full custom design. Further, due to advancement in the integration technology, the semi custom design field is emerged, resulting in to the VLSI devices like CPLD and FPGA. These devices include configurable blocks and programmable interconnects and flash memories with which one can ensure the digital electronic system design [2]. It is found that, for electronic system design, in addition to digital design analog part is also equally important [3]. Therefore, now days a new technologyis emerged wherein both analog as well as digital design is considered. Such technology is referred as Analog and Mixed Signal Based Programmable System on Chip (AMS-PSoC) design [4]. In case of electronic system design the mixed signal technology, where in both analog plus digital parts, are essential. Considering this fact into account the Cypress corporations are providing programmable system on chip to focus the mixed signal VLSI design. The Actel and Cypress are playing vital role in this field [5, 6]. The cypress are providing mixed signal PSoC in three generations PSoC 1, PSoC 3 and PSoC 5, having commendable salient features.

On survey, it is found that the designers are attracting towards the field of embedded development to design an electronic instrument for monitoring the various physical as well as chemical parameters [7, 8, 9]. Monitoring of various environmental parameters is needed in the various sectors such as industries, medical, domestic etc. Out of these fields the field of agriculture is mostly demanding sophisticated instruments. The farmers are demanding the system to monitor the parameters like humidity, temperature, light intensity, carbon dioxide etc. Considering thisfacts, and the social demands, it is proposed to undertake the project work to measure environmental parameters of polyhouse by using innovative technology of the mixed signal SoC design. The relentless efforts of the scientists and designing engineers results into the emergence of different field for electronic research. Recently, Wireless Sensor Network (WSN) is the revolutionary field depicting wide spectrum of applications [10]. The wireless sensor network is distributed collaboration of various sensing devices called Sensor Nodes and the Base Station [11]. The performance of the WSN is solely depends upon the features of wireless sensor node and the technology adopted for establishment of wireless communication. For wireless communication the ZigBee Technology is playing commendable role.The ZigBee Technology is resulting into the device “XBee” for RF communication. The XBee is also the best example of development of system on chip for dedicated application. This is operating according to the standards laid down by the IEEE 802.15.4 at 2.4 GHz in ISM band [12]. Moreover, the microcontrollers from different families have been used as computing unit required to facilitate the sensor node. For development of sensor node to typical WSN based on SoC are rather rare. The technologyof Analog and Mixed Signal Based Programmable System on Chip (AMS-PSoC) is recently emerged. Therefore, it is proposed to undertake the project work on deployment of AMS-PSoC technology for sensor node. Deploying PSoC 1 the sensor node is designed for typical environmental parameters, wherein ZigBee technology is realized for wireless comm. The developed embedded system is truly SoC and results of the implementation are interpreted in this paper.

II. Mixed Signal Based PSoC

A System-on-a-Chip or System-on-Chip (SoC) is an integrated circuit (IC) that integrates all components of a computer or other electronic system into a single chip. It may contain digital, analog, mixed-signal, and often radio-

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frequency functions all on a single chip substrate [13]. A typical application is in the area of embedded systems are more famous. Microcontrollers typically have under 100 kb of RAM (often just a few kilobytes) and often really on single-chip-systems, whereas the term SoC is typically used with more powerful processors, capable of running software such as the desktop versions of Windows and Linux, which need external memory chips (flash, RAM) to be useful, and which are used with various external peripherals [14]. The increasing chip integration to reduce manufacturing costs and to enable smaller systems. Many interesting systems are too complex to fit on just one chip built with a process optimized for just one of the system' task.

Mixed signal System-on-Chip is a relatively complex stand-alone system on a single semiconductor chip containing processor core, analog parts, digital parts and smart interfaces.A mixed-signal integrated circuit is any integrated circuit that has both analog circuits and digital circuits on a single semiconductor die. Typically, mixed-signal chips perform some whole function or sub-function in a larger assembly such as the radio subsystem of a cell phone, or the read data path and laser sled control logic of a DVD player. They often contain an entire System-on-a-Chip as shown in figure 1. The implementation uses PSoC programmable mixed-signal embedded System-on-Chip, which incorporates microcontroller, on-chip SRAM and flash memory.

The mixed-signal integrated circuits include data converters using delta-sigma modulation, analog-to-digital converter/digital-to-analog converter using error detection and correction, and digital radio chips. Digitally controlled sound chips are also mixed-signal circuits. With the advent of cellular technology and network technology this category now includes cellular telephone, software radio, LAN and WAN router integrated circuits. Because of the use of both digital signal processing and analog circuitry, mixed-signal ICs are usually designed for a very specific purpose and their design requires a high level of expertise and careful use of Computer Aided Design (CAD) tools. Automated testing of the finished chips can also be challenging. Teradyne, Agilent, and Texas Instruments are the major suppliers of the test equipment for mixed-signal chips. The companies like Actel, Cypress and Microsemi provide a mixed-signal SoC technology based on FPGAs.

A.PSoCDesign Flow

- Determine system requirements
- Choose User Modules
- Place User Modules
- Set global and User Module parameters
- Define the pin-out for the device
- Generate the application
- Review generated code
- Demonstrate working configuration

III. WIRELESS SENSOR NODE BASED ON PSoC

Indeed, deployment of sophisticated technology like PSoCresults into modernization in the instrumentation. Therefore, to develop the Wireless Sensor Network (WSN) two technologies such as analog and mixed signal based programmable system on chip design and ZigBee technology are availed. The sensor node is designed to monitor relative humidity of the environment realizing site specific variability.

For the present research work out of various environmental parameters, the parameters, such as humidity, CO2 concentration, temperature, light intensity, moisture, etc. the humidity measurement will be considered for designing of the System-on-Chip (SoC). For this design the Programmable System-on-Chip (PSoC) device CY8C29466 is used. The suitable sensors available for humidity measurement are employed. The analog parts of the

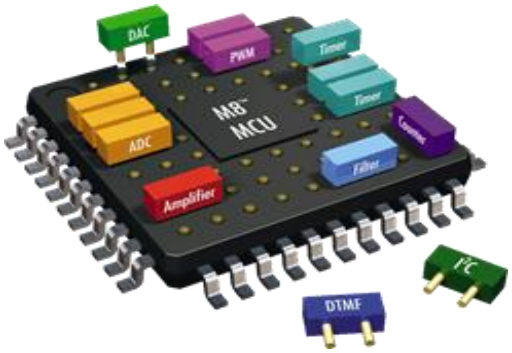

Figure-1. The System-on-a-Chip

hardware, such as data Acquisition System (DAS), signal conditioning etc. are designed with the help of the analog resources provided by the PSoC device. Using PSoC Designer 5.1 Integrated Development Environment (IDE) the analog blocks are configured and software will be co-developed and implemented for this design. The analog resources are dynamically reconfigured for low power, low cost.

As shown in figure 2 the system is designed about CY8C29466-24PXI PSoC device. The humidity sensor SY-HS-220 is employed for measurement of humidity [15]. It is found that, the sensor exhibiting linear characteristic. The humidity sensor provide humidity dependent output DC voltage in the millivolt (mV) range.This potential is in the mV range and should be amplified, for this purpose analog block PGA (Programmable Gain Amplifier) is configured. The humidity dependent signals are physically connected to the PSoC device, where we configured PGA as analog block for pickup the signal and analog to digital conversions (ADCs) for digitization and further processing. The analog voltage is digitalized by the configuration of ADC incremental variable resolution, which works on the principle

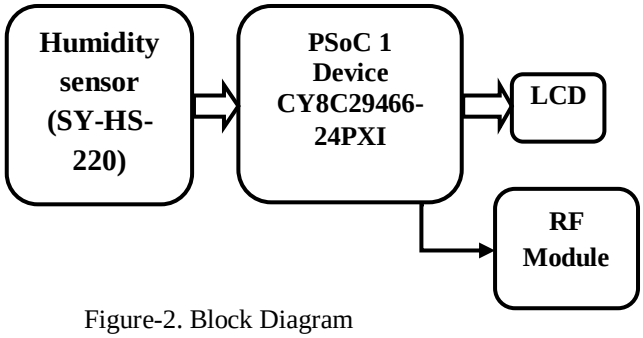

Figure-2. Block Diagram

of successive approximation. The ADC is configured for 13 bit resolution. Normally, in case of microcontroller the ADC of 8 bit, 10 bit and 12 bit resolution are available. Actually, cypress PSoC facilitates the 8 to 20 bits. However, this facility is made available for sigma-delta modulation ADC. The output is expected to be in unit of humidity i.e. relative humidity(RH %). Therefore, the system is calibrated. In order to insure the digital readout, the smart LCD from Hitachi is

used in 4-bit configuration mode.For signal interfacing to the peripheral devices USART port 1of CY8C29466-24PXI PSoC device is configured. Moreover, to realize the wireless communication, ZigBee device is connected to the USART port 1 of PSoC.

A.The Humidity sensor

As discussed earlier, Humidity sensor SY-HS-220 is wired with the PSoC device [15]. The humidity sensor SY-HS-220 has number silent features. The humidity sensor is equipped along with the signal conditioning stages on a single board. The humidity sensor is of capacitive type, comprising on chip signal conditioner make sensor rather smarter. Sensor Board consists of oscillator, AC amplifier, frequency to voltage converter and precision rectifiers. The Figure 3 depicts Humidity Sensor SY-HS-220. Incorporation of such stages on the board significantly helps to enhance the

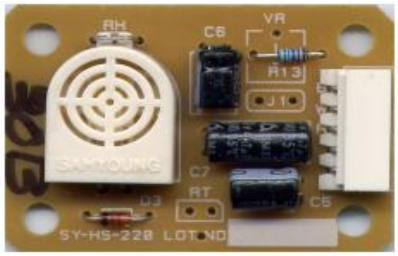

Figure-3 Humidity sensor(SY-HS-220)

performance of the sensor. Moreover, it helps to provide impediment to the noise. The Printed Circuit Board (PCB) unit also consist thermistor and diode for temperature compensation.The humidity sensor used because it is highly precise and reliable. It can be a smart sensor, which provides DC voltage depending upon humidity of the surrounding in RH%. This work with +5 Volt power supply and the typical current consumption is less than 3 mA. The operating humidity range is 30% RH to 90% RH. The standard DC output voltage provided at 25^0C is 1980 mV. The sensor accuracy is±5% RH at 25^0C [16].

B. RF Module

ZigBee is a wireless communication module that Digi built to the 802.15.4/ZigBee standard. The beauty of the 802.15.4/ZigBee wireless standard is that it can form self-healing mesh networks. These are great for making a wireless control network. By default, the modules are configured from the factory to be a wireless serial line replacement. It can be programmed to do other functions like behave as a "wireless wire" where a level transition on an input pin of one module is sent out as the same level transition on a different module output pin. The ZigBee device is of 20 PIN in Duel in Line Package, the figure 4 shows the ZigBee device [17, 18]. The ZigBee devices are configured by two ways as API and CT mode for data transmit onto the network [19]. ZigBee technology allows wireless networking to connect several units to control through one button like in business industry. This wireless networking avoids the threat of short circuiting. Centralization control system reduces the man power. As a wireless communication system ZigBee technology helps to monitor the activities and manipulates in a better way. It is operates in 2.4 GHz Industrial Scientific and Medical (ISM) band. Its Indoor/Urban range is up to 100 ft (30 m) and outdoor/RF line-of-sight range isup to 300 ft (90 m). The RF data rate is about 250 Kbps.

Figure 4: The ZigBee device

IV. SOFTWARE

The development of an embedded system involves two major components such as hardware and software. The software or firmware is co-developed in embedded C language using PSoC Designer 5.1 development tool. The PSoC Designer consists of various subsystems. By using the subsystems a firmware is developed to measure relative humidity of the environment. The process of development of an embedded system using PSoC is divided in to three parts; Design of the hardware, Configuration of the each analog and digital blocks and Developing firmware. The system designed is routed on to the chip and configured according the requirements. The configured hardware through PSoC designer and developed firmware both are programmed in to the on-chip memory of PSoC 1. The prototype of the sensor node using PSoC is depicted in figure 5.

To developWireless Sensor Network to monitor humidity of area under investigation, the four Sensor Nodes are developed. In addition to this the base station is designed to collect and demonstrate the relative humidity of the area under investigation. The developed WSN is ready for implementation.

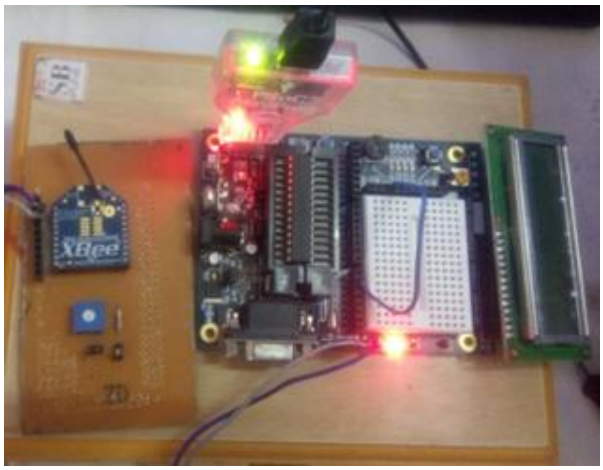

Figure 5: The prototype of the Sensor Node

V. EXPERIMENTAL

Emphasizing the innovative field of mixed signal based SoC design, the project work is undertaken. For this project work the PSoC 1 is used. As per the proposal system is developed for measurement of humidity of the environment using CY8C29466-24PXI microcontroller.By configuring the analog and digital blocks of the PSoC and integrating respective intelligence, the system is designed. To measure humidity a smart sensor SY-HS-220 are employed respectively. Actually, in normal state, the air of the laboratory at room temperature contains water molecules. Because, of which the sensor is exhibiting the emf about 926mV. This voltage must be compensated. This voltage is compensated by the software. Hence, the system is subjected to process of calibration, particularly for the humidity. The system is calibrated by using highly accurate and automatic humidity chamber, Gayatri scientific, Mumbai.

Figure6presents the experimental arrangement for calibration of the SY-HS-220 humidity sensor. The standard humidity is applied by using humidity chamber and the humidity dependent emf is recorded. Same is plotted with respect to standard humidity as shown in figure 7.The empirical relation obtained from fitting procedure is

Figure 6: Experimental Setup

VH = 33.65 SH -127.2 … (1)

Where, VH is standard humidity dependent emf in mV and SH is standard humidity applied by Humidity chamber in RH %.

Thus the calibration factor is determined is,

Standard Humidity (SH) in RH % = (VH+127.2)/33.65)… (2)

This calibration equation is implemented in software. Thus the observed readings are displayed on LCD in relative humidity in RH% as well as same are transmitted towards base station.

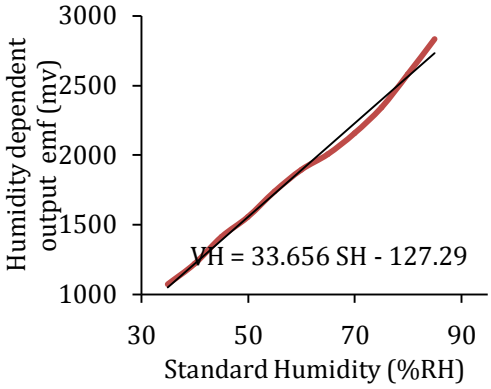

Figure 7: Calibration curve for humidity

Network is established in the college lawn. Figure8 depicts the establishment of WSN in college lawn.

VII. RESULT AND DISCUSSION

On literature survey, it is found that the regarding humidity, percentage of water vapor dissolve in the air, the data is highly important particularly in case of the poly houses where the crops are grown, in controlled environment. It is found that, the agriculturists are demanding highly sophisticated and reliable system for humidity measurement. Considering the need of hour, the system is designed for humidity measurement.As discussed earlier system is designed and calibrated for RH % unit. After successfully locating of the sensor nodes, the readings are taken for different time period of different days. The typical data collected by WSN is shown in table 1. On the observation of recorded data by sensor Node 1 to 4, the humidity is varies with respect to location to location as well as time. It is found that, the average humidity of area under investigation is about 33.35 RH % to 34.05.


Figure 8: Implementation of the PSoC base Sensor Node to Monitor Humidity

VI. IMPLEMENTATION OF WIRELESSSENSOR NETWORK

To ensure proper operation and to confirm accuracy and reliability and to realize the phenomenon of collaborative collection of environmental data, the present Wireless Sensor

VIII. CONCLUSION

A mixed signal PSoC based system is designed for measurement of humidity of the environment. Using Cypress PSoC microcontroller the system is developed by reconfiguring the Analog as well as Digital blocks of the PSoC. Deploying the IDE provided by the Cypress, the

necessary firmware is developed and integrated to ensure the embedded system on chip design. The humidity observations shown by the system are highly reliable and precise. On inspection of the result of implementation, it can be concluded that the present system works successfully and gives the data regarding humidity in the environment very precisely.

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