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Development of Smart Fusion Technology Based System for Light Intensity Measurement for Polyhouse

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ABSTRACT

Recently, the system-on-chip capabilities provide the opportunity to have more flexibility in system design. Mixed Signal Devices (MSD) combines Analog and Digital processing elements in a single device. SmartFusion customizable System-on-Chip (cSoC) devices integrate an FPGA, an ARM Cortex-M3 processor and programmable analog, offering full customization, IP protection and ease-of-use. Deploying reconfigurable resources of Smart Fusion device, A2F200M3F, a customizable system on chip is designed dedicatedly for polyhouse application. The light intensity sensor BPW34 is used for present design. It is more sensitive to the Sunlight rather than any other sources. For growth of plants in agriculture, intensity of light is one of the important parameter. Therefore, system is designed for measurement of intensity of light. An IDE LiberoSoC is used for design and customizing of hardware for the system-on-chip, whereas the firmware is co-designed by employing SoftConsole. The designed system exhibits high reliability and high preciseness.

Keywords : Mixed Signal SoC, Polyhouse parameters, BPW34, reconfigurability, MSS, ACE.

I. INTRODUCTION

Recently, the system-on-chip capabilities provide the opportunity to have more flexible system design [1]. Traditionally SoC devices like CPLD and FPGA are used, but FPGA based design technology having lack of flexibility. These FPGA has fixed hardware implementation. So FPGA with core based approach, intellectual property (IP) cores, pre-designed hardware with reconfigurable logic blocks and reprogrammable processor core on same chip has been proposed as solution to ensure more flexibility [2]. Moreover, these devices provide only digital solution. The mixed signal based system on chip design is immerged to ensure analog as well as digital design in single chip [3-5]. These mixed signal based technologies contain both reconfigurable analog and digital blocks along with processor core and communication peripherals [6]. The hardware and software component interact in order to perform application task. Such systems need a co-designing to build a flexible embedded system [7]. So this paper focuses on the implementation of the mixed signal based SoC design for measurement of intensity of light using of Smart Fusion technology for agriculture applications.

II. ANALOG AND MIXED SIGNAL BASED EMBEDDED SYSTEM FOR AGRICULTURE APPLICATION

A. *The System Architecture*

This paper emphasizes the designing of an embedded system, wherein the principle of mixed signal based VLSI design is employed. According to the salient features, an embedded system comprises both hardware as well as firmware. Both hardware and software are designed and details regarding their design are illustrated through following two points.

- The Hardware
- The Software

B. *The Hardware*

Analog and mixed signal technology of VLSI design exhibits commendable growth, wherein analog as well as digital cores are reconfigured. Present system is developed about Smart Fusion technology based customizable System-on-Chip (cSoC), A2F200M3F, from Microsemi, USA. Figure 1 shows system under design. It consists three main parts,

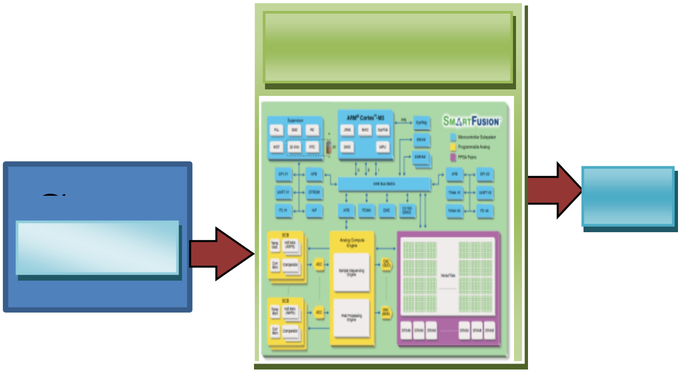

Figure 1: Block Diagram of the System-on-Chip designed to monitor polyhouse parameters.

1) *Sensors Unit:* For agriculture, the environmental parameters such as intensity of light etc should be essentially monitored. To measure these parameters, the sensors of promising characteristics must be used. For this purpose light intensity sensor (BPW34) is used. These sensors are externally interfaced to cSoC device. The output of respective sensor is given to cSoC device for further processing. The design issues of each part of this sensor array are described. Figure 2 shows the light intensity sensor BPW 34. The sensor BPW34 is a PIN photodiode with high speed and high radiant sensitivity. It is sensitive to visible and near infrared radiation and the angle of half sensitivity is ± 65° [8]. Moreover, it is also found that this sensor is more sensitive to sunlight than other light sources. For present system 1K Ohm register (Figure 3) is used at output of sensor to achieve output in voltage (mV) form. Light intensity dependent voltage is measured and given to ABPS7 pin of SmartFusion device for further process. The required analog part is design in System-on-Chip.

2) *Customizable System-on-Chip (cSoC) Device (A2F200M3F):* The mixed signal FPGA is first introduced in fusion technology in which in addition to FPGA, the programmable analog blocks, configurable digital cores and soft processor cores are available. This technology is extended to SmartFusion. It provides more flexibility and configurability, highly reduced power consumption as well as fast system development time. For present system the SmartFusion A2F200M3F device from microsemi is used. Figure 3 depicts the architecture of SmartFusion A2F200M3F device. It comprises following parts of significant configurability.

- Programmable Analog block
- Microcontroller SubSystem
- FPGA fabric.
- Communication Interfaces
- IO Ports

The programmable analog block of the cSoC plays significant role to realize the mixed signal based VLSI design. On chip programmable analog block consists of Analog Front End (AFE) and Analog Compute Engine (ACE) and analog to digital converter (ADC), ∑Δ Digital to Analog Converter (DAC) and high performance analog Signal Conditioning Block (SCB) [9]. This analog block plays vital role in the process of calibration of the system in engineering unit, as well. The SmartFusion technology based cSoC consist of ADC with reconfigurable 8, 10, and 12 bit resolution [10].

The SmartFusion device consists of processing sub system called as Microcontroller SubSystem (MSS). The MSS of SmartFusion is composed of 32-bit, 100 MHz CortexM3 processor, internal memory blocks, clocking resources and integrated peripherals, which are interconnected via a multilayer AHB bus matrix (ABM). It provides debug facilities with JTAG and serial wire. The different sets of peripherals are also available, which includes the components such as 10/100 Ethernet MAC, UARTs, SPI, GPIO, Timers, clock resources, two I2C peripherals etc. As per need of system, out of two I2C one I2C peripheral is used for interfacing of Organic (OLED) based smart LCD to display the processed data.

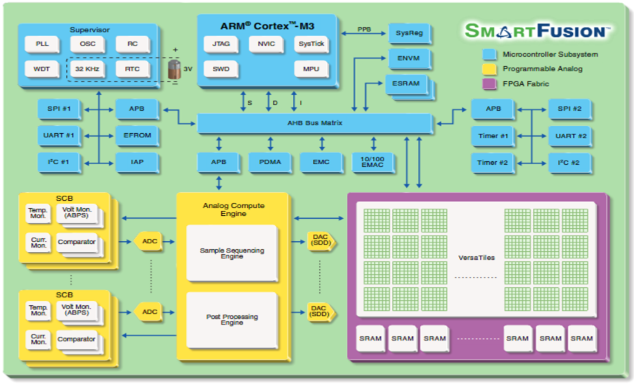

Figure 2: Architecture of Smart Fusion device A2F200M3F

To ensure customising and routing, the configurable platform is essential. Therefore, the SmartFusion device A2F200M3F consists of FPGA platform to ensure integrability of the primitives.

Traditionally, for alpha numeric display, the smart LCD of 16x2 lines is employed. However, it consumes rather more power. Recently, organic light emitting diode (OLED) introduced. In present system, instead of crystalline display the OLED display is employed. This low power device, BLUE OLED, requires 3.3 V power supply. The OLED is interfaced with the SmartFusion MSS using I2C port [11].

Figure 3: Light Intensity Sensor (PIN Diode BPW 34)

III. THE SCHEMATIC OF THE CIRCUIT

Present system realizes the design of mixed signal based programmable System-on-Chip. As shown in figure 4, the necessary primitives are configured and integrated into one single chip.

On-chip signal conditioning features of SmartFusion device is used, wherein the light intensity sensor (BPW34) is directly interfaced to the SmartFusion device. The output of this sensor is in the voltage form. Therefore, this signal is given to the Active Bipolar Prescaler (ABPS) block, which is voltage monitoring block of the SCB of SmartFusion device. The light intensity sensor (BPW34) exhibits linear variation in the current with respect to the intensity of light. This current varying signal is converted into voltage and then interfaced. The output of this light intensity sensor given to ABPS7 pin of SCB3 and prescaler input range set to ±5.12V. Output of these ABPS is given to channel 6 of multiplexer and multiplexer output given to ADC1. The output of ADC is given to Analog Compute Engine (ACE), wherein sampling, sequencing, post processing etc. are done. Through, Advanced Peripheral Bus (APB), the digital output of ACE is given to cortexM3 based microcontroller subsystem for processing the data.

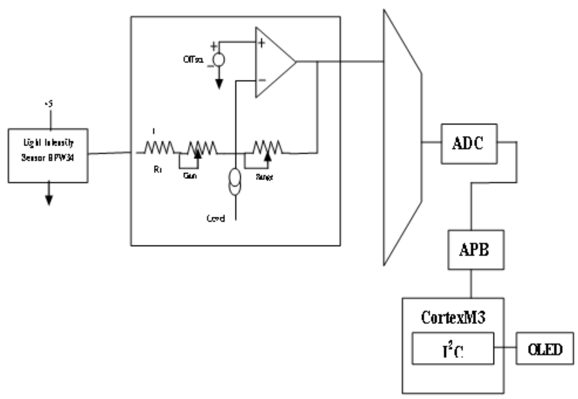

Figure 4: View of the circuit synthesized by adopting LiberoSoC on the chip A2F200M3F.

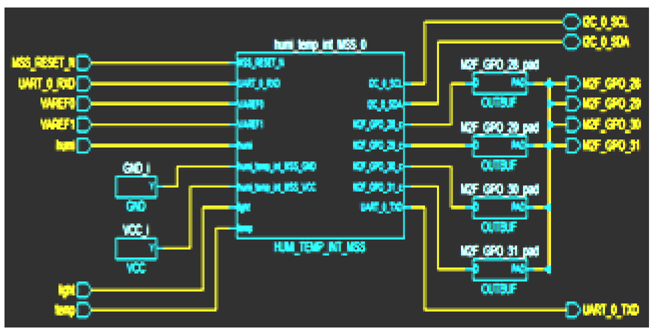

Figure 5: Schematic of designed system on chip.

The final system designed in Libero SoC shown in figure 5.

IV. THE FIRMWARE

The application code for hardware is developed in embedded C environment for which the IDE SoftConsole is deployed. The Deploying FlashPro programmer the device is programmed with .hex file. Thus, the system-on-Chip is co-developed to monitor agriculture parameter.

V. RESULTS AND DISCUSSION

The light intensity, amount of light energy falling on the crops plays vital role on crop growth. The photosynthesis process is always taking place in presence of the sun light. Therefore, measurement of sunlight intensity is important. In present system the sun light intensity is measured for different time domains in open environment, shown in figure 6.

However, as per need of sophisticated instrumentation, the parameter light intensity must be in respective engineering units and it is Lux. Therefore, the calibration of the system under the investigation is essential and so, the system is further subjected to the process of calibration.

In the beginning a light intensity dependent voltage, V_{LI}, is measured for entire range from darkness to air (sun light) conditions to the condensation of sun light. It is known that, the condensation of sun light occurs if air gets saturated with sun light. Thus, the light intensity dependent voltages are recorded up to saturation point on developed system against the standard Digital Lux Meter make MS6610 from Mastech. For more accuracy and reliability of the developed system the three iterations are recorded for same variable environmental conditions and then it is averaged and plotted. The graphs of observed emf, V_{LI}, in mV against light intensity applied are shown in figure 7.

Figure 6: The experimental setup of the present system for calibration procedure.

From these calibration graphs, it can be said that, the relation of observed emf, V_{LI}, with light intensity applied is quite linear through the entire range of investigation. So, to find the respective empirical relations, the curve is subjected to the statistical process of regression. The linear empirical relation obtained is as follows.

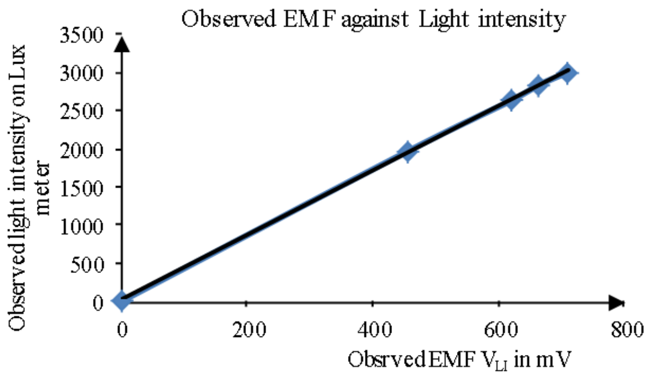

Figure 7: The experimental setup of the present system for calibration procedure.

$$\text{Light Intensity in Lux} = (4.2398 \times V_{LI}) + 8.677$$

This equation is employed in the firmware, to standardize the developed system in Lux unit. Thus, the developed system is calibrated and standardized to light intensity scale in scientific unit Lux.

Furthermore to validate the developed system and to ensure light intensity measurement, it is subjected to measure the varying light intensity environment along with same digital Lux meter. The observations on developed system against digital Lux meter are recorded for number of iterations and the same light intensity data is recorded at each time. The graph of observed light intensity in Lux on developed system against applied light intensity on digital Lux meter is plotted and shown in figure 8. On inspection of the figure 8, it is found that, the light intensity values observed on mixed signal based system on chip are precise and shows a good agreement in most of all the cases to each other and also shows a good agreement with the standard digital Lux meter. This validates the developed system based on Smart Fusion Technology for precise light intensity measurements of agriculture environment.

Thus the present System-on-Chip is calibrated to standard units Lux and it is implemented to ensure agriculture application.

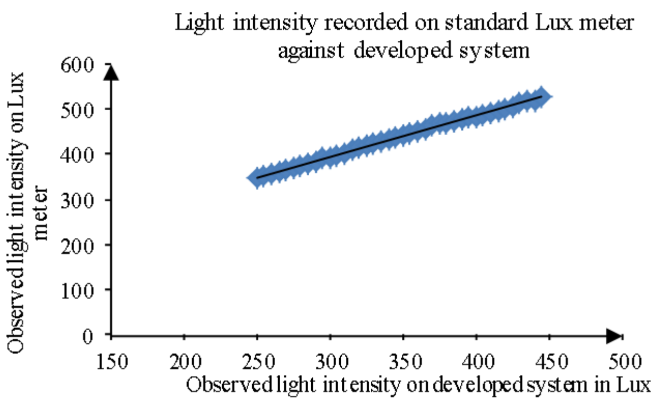

Figure 8: The plot of light intensity observed on developed system and Lux meter.

VI. CONCLUSION

The system is designed for precision agriculture and implemented for measurement of intensity of light. Realizing the reconfigurability of both hardware and software are co-developed. The intensity of light is calibrated in percentage for the simplicity. The results obtained from the system under investigation reveal the reliability of the system.

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