



Design and Implementation of a Smart Fire Extinguisher using FPGA

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ABSTRACT: This paper presents the design and Implementation of a smart fire extinguisher using FPGA. In this design, two temperature sensors mounted on a servo motor are used to locate the position of the fire. The movement of the servo motor is done through pulse width modulation (PWM) which has been written using verilog code. The implementation is done in a Spartan-6 FPGA board. The test result shows that the time required to detect the fire is approximately 20ms. The fire extinguisher is getting activated within 50ms (approximately) of the detection of the fire. The complete design utilizes 32 Slice Registers and 73 Slice LUTs.

KEYWORDS: FPGA, LUT, Spartan-6, Verilog, PWM

I. INTRODUCTION

Home fire detection is a matter of great concern and thus needs an automatic detection system. Many efforts are devoted in most developed countries to the design of automatic fire detection systems [1], [2]. It is very critical for the personal security and commercial applications.

An automatic fire detection system should reliably and timely alert the residents about the presence of fire indicators, such as smoke or high temperatures. In general a fire detector is usually implemented as a smoke sensor [3] due to its early fire detection capability, fast response time and relatively low cost. Other options for the fire detection are based on gas sensors [4], [5], [6] or temperature sensors. Fire detectors that use a single sensor, generally a smoke sensor, present high false-alarm rates due to temperature changes [2], [7].

In literature [1] and [2], *J. Vicente et al.* and *V. Cappellini et al.* demonstrated the importance and need of designing a smart fire extinguisher. Smart fire extinguishers can be applicable to all areas of fire prevention and protection. It addresses all phases of resilience (i.e pre-incident, during incident and post-incident). *Van Nguyen et al.*[3], *Patricio et al.*[4] and *Chance et al.*[5] have introduced various instructions and guidelines to use the smart fire extinguisher. Fire prevention is generally achieved by enhancing the power of information through enhanced data gathering, processing and targeted communication. Various implementation techniques for different fire extinguishers are described in [6] and [7].

In this paper, the design of a smart fire extinguisher is presented which has been implemented in Spartan-6 FPGA board and successfully tested. The detection of fire takes approximately 20ms and the fire extinguisher gets activated within 50ms of the detection of the fire. The organization of this paper is as follows: Section 2 introduces the Architecture and implementation of the smart fire extinguisher. Section 3 elaborates the results and discussion of the smart fire extinguisher. Finally, Section 4 concludes the paper.

II. ARCHITECTURE AND IMPLEMENTATION OF THE SMART FIRE EXTINGUISHER

The block diagram of the smart fire extinguisher is shown in Fig. 1. At the front end two temperature sensors are used (LM 35). The temperature change sensed by the temperature sensor is converted to analog voltage by using driver circuits. The driver circuit is designed using two BC547 transistors. Fig. 2 shows the schematic of the driver circuit. The output of the driver circuits are connected to the inputs of the Analog-to-Digital Converters (ADC-1 and ADC-2). Here we have used ADC0804 IC. The circuit connection of ADC0804 is shown in Fig. 3.

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The design has been implemented using Spartan-6 FPGA board. The summary shows that the design utilizes 32 Slice Registers and 73 Slice LUTs. The design summary result has been shown in Fig 4.

Fire_Extinguisher Project Status			
Project File:	RCServo.xise	Parser Errors:	No Errors
Module Name:	Fire_Extinguisher	Implementation State:	Synthesized
Target Device:	xc6slx9-3csg324	Errors:	No Errors
Product Version:	ISE 13.4	Warnings:	3 Warnings (3 new)
Design Goal:	Balanced	Routing Results:	
Design Strategy:	Xilinx Default (unlocked)	Timing Constraints:	
Environment:	System Settings	Final Timing Score:	

Device Utilization Summary (estimated values)			
Logic Utilization	Used	Available	Utilization
Number of Slice Registers	40	11440	0%
Number of Slice LUTs	73	5720	1%
Number of fully used LUT-FF pairs	33	80	41%
Number of bonded IOBs	27	200	13%
Number of BUFG/BUFGCTRLs	1	16	6%

Fig. 4: Design summary of the smart fire extinguisher

The RTL Schematic and the Technology Schematic are shown in Fig. 5 and 6 respectively.

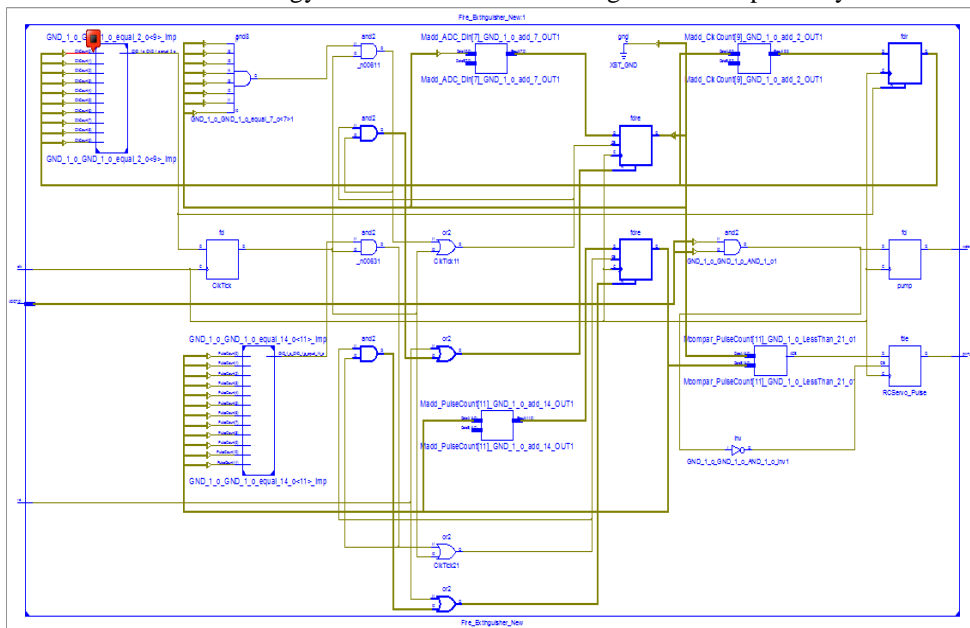


Fig. 5: RTL Schematic of smart fire extinguisher

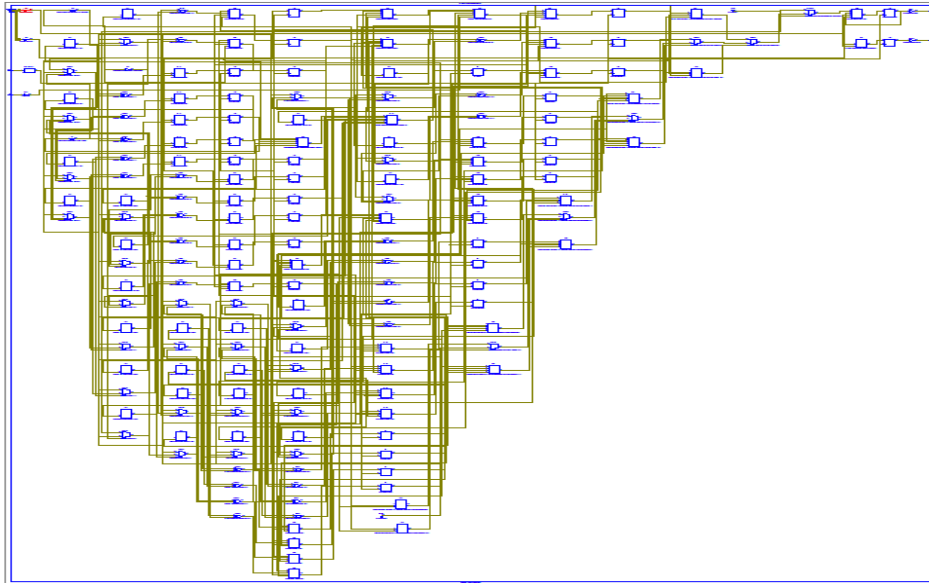


Fig. 6: Technology Schematic of smart fire extinguisher

Fig. 7 shows the FPGA board which has been used to implement the smart fire extinguisher. In this board Spartan-6 FPGA is used. A crystal oscillator generating a clock of 100MHz is used as the clock pulse for this Spartan-6 FPGA. This module uses +5V power supply to function properly. By default the board is configured to use +5V supply from USB. So an external +5V power is not required unless USB port is unable to supply enough current. This board is equipped with 32 user IO pins that can be used for various custom applications. For our design, we have used these IO pins for connecting the ADC outputs and DAC input. Also to drive the servo motor these ports are used.

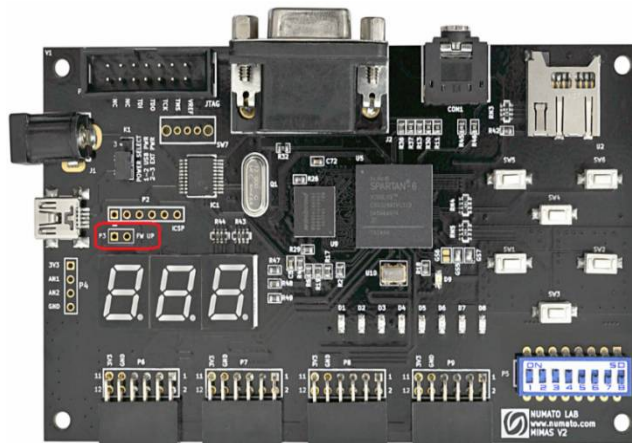


Fig. 7: Spartan-6 FPGA board

The circuit board used for interfacing the temperature sensors, FPGA Board, servo motor and the water pump is shown in Fig. 8. As shown in Fig. 8, the first section is power supply which is designed using a LM7805 voltage regulator. The 5V output of this regulator is used to power up the ADCs, DAC, the temperature sensor driver circuits and the servo motor.

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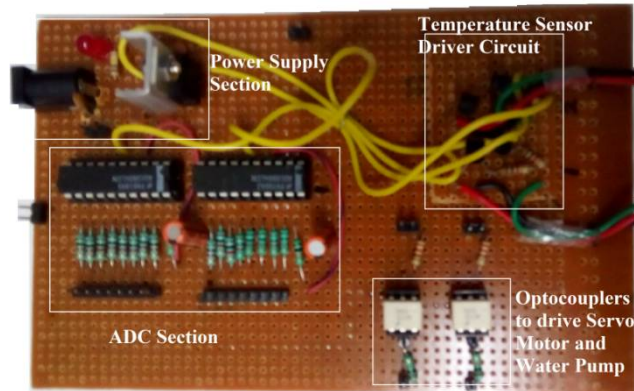


Fig. 8: Circuit board used to interface FPGA, servo motor and the water pump

The water pump needs a power supply of 12V which is given from another power supply. For sensing the temperature generated from fire, we have used LM35 temperature sensor. The driver circuit is designed using two BC547 transistors. The resistivity of the temperature sensor changes with the change in temperature which determines the output of the driver circuit. When the temperature is low, the output is low and with the increase in temperature, the output also increases.

III. RESULT AND DISCUSSION

The simulation result of the smart fire extinguisher is shown in Fig. 9 (a) and (b) respectively. As shown in Fig. 9(a), the PWM pulse is increasing gradually because the value of ADC-1 is greater than ADC-2. The PWM is necessary to control the position of the servo motor.

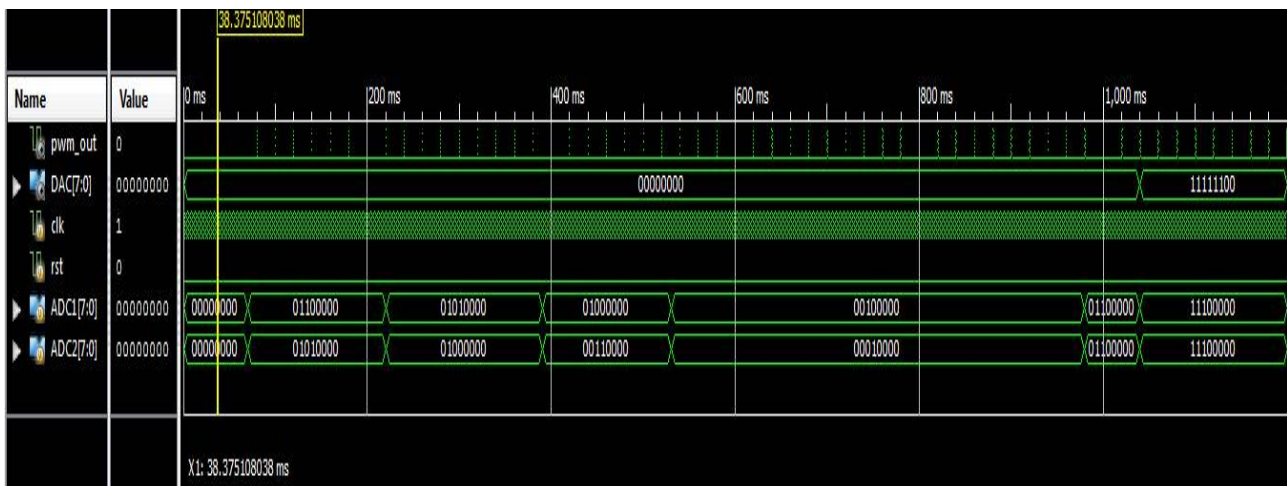


Fig. 9(a) Test bench simulation results of the smart fire extinguisher with 1200ms time period

From the simulation result, the time period required to operate the servomotor is found to be 20ms and the pulse width varies from 0.5ms to 2.5ms. Since, the ADC has 8-bit output, so there are 255 positions ($2^8 - 1$) for the servomotor. As Spartan-6 FPGA operates at 100MHz clock, a time division has been done through verilog code in order to operate the servomotor. The DAC value remains zero as long as the seventh bit of both the inputs ADC-1 and ADC-2 are '0'. When the seventh bit of both the inputs ADC-1 and ADC-2 are '1', the DAC becomes active and allows the pump to

pour water on the fire. The value of DAC will gradually decrease with the decrease in temperature. This helps in saving water and hence results in better water and power management.

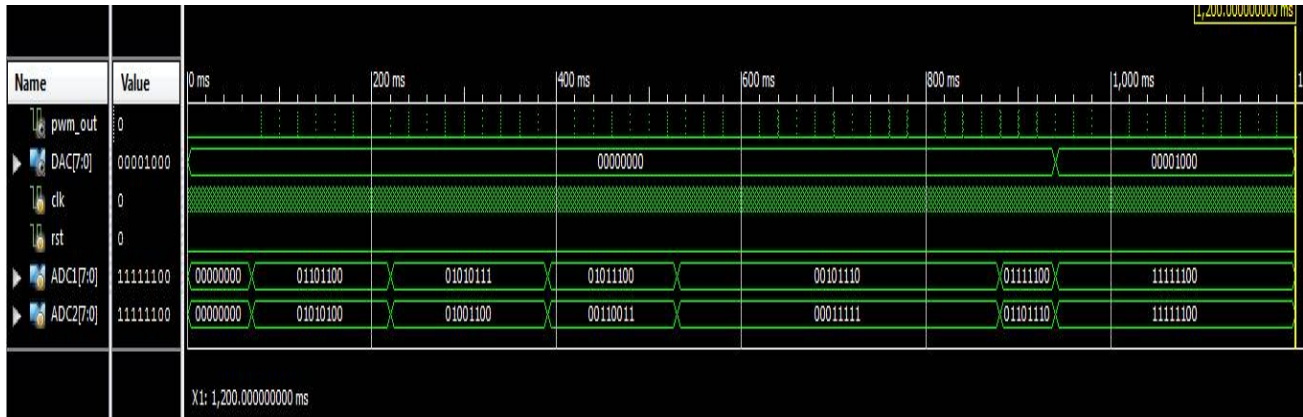


Fig. 9(b): Test bench simulation results of the smart fire extinguisher with 1200ms time period

IV. CONCLUSION

In this paper, a smart fire extinguisher is designed using Field Programmable Gate Array which utilizes 32 slice registers and 73 slice LUTs. The design has been implemented in a Spartan-6 FPGA board. The test result shows that the time required to detect the fire is approximately 20ms. The fire extinguisher is getting activated within 50ms approximately of the detection of fire. Therefore, this fire extinguisher can be used effectively in buildings where chances of fire occurrence are more.

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