Design and Implementation of FPGA Based Quadcopter

G Premkumar[1]

SCSVMV, Kanchipuram, Tamil Nadu, INDIA

R Jayalakshmi[2]

Assistant Professor, SCSVMV, Kanchipuram, Tamil Nadu, INDIA

Md Akramuddin[3]

Project Engineer-II, Centre for Development of Advanced Computing

(C-DAC), Hyderabad, Telangana State, India.

ABSTRACT

This work aims to design and implement a digital flight controller on a FPGA prototype board for stabilizing a Quadcopter unmanned aerial vehicle (UAV). The purpose of the project was to access the feasibility of using an FPGA in the stabilized control of an under actuated aerial robotic system. Generally, FPGAs are good for implementing time critical concurrent processing functions. ESC and PWM decoder are good examples, but also IMU integration. The flight controller on the craft is custom made FPGA board.It employs Field Programmable Gate Array (FPGA) and Digital Signal Processor (DSP) technology to satisfy the requirements for more advanced vehicle behaviour in a small package. Having these two processors in the system enables custom vehicle interfacing and fast sequential processing of high-level control algorithms.

KEYWORDS:UAV, FPGA, DSP, RC, IMU, PID, ESC,YPR, DMP.

I.INTRODUCTION

Un-manned aerial vehicles are important nowadays for many applications and experimentation activities. These UAV's are business leading systems, designed by us for many applications like 3-D modelling, volumetric analysis, mining, agriculture, surveying etc. Actually these drones are classified into 2 types, they are fixed wing and rotary wing, again this rotary wing is classified into 2 types, and they are single rotor and multi-rotor. The merits and the demerits of drone types is described in below table. Quad-copter is also called as quad-rotor. it is a multi-rotor helicopter that is lifted and propelled by four motors. By changing the speed of each rotor it is possible to specifically generate a desired total thrust, The most common rotor configuration is two rotors rotate in clockwise (CW) and other two in counter clockwise (CCW) direction the Quadcopters have many configurations like ' X ' , ' + ' , ' H '. X is preferred when high speeds & manoeuvrability is required since only 2 rotors need to bank left or right. The quad-copter control comes from the variations in the torque from the motors and thrust, to locate for the centre of thrust both laterally and longitudinally; and to create a desired total torque, or turning force. The main advantage of this quad-rotor is vertical take off and landing.

In this project we are designing the quad-copter with FPGA flight controller, also we can use the drone at night times .This quad-copter is Operable at different weather conditions, to sustain this we have to implement the PID control algorithm with high accuracy and the type of the material used for the drone frame should have more density and less weight [1].

II. Proposed system

It shows the modules of the block diagram that can be implemented and run on FPGA for stable hovering of the Quadcopter. It consists of the sensors, FPGA, ESC's and the motors. The inputs to the flight controller are taken from MPU-6050, ultrasonic sensor and radio controller (RC) [3].
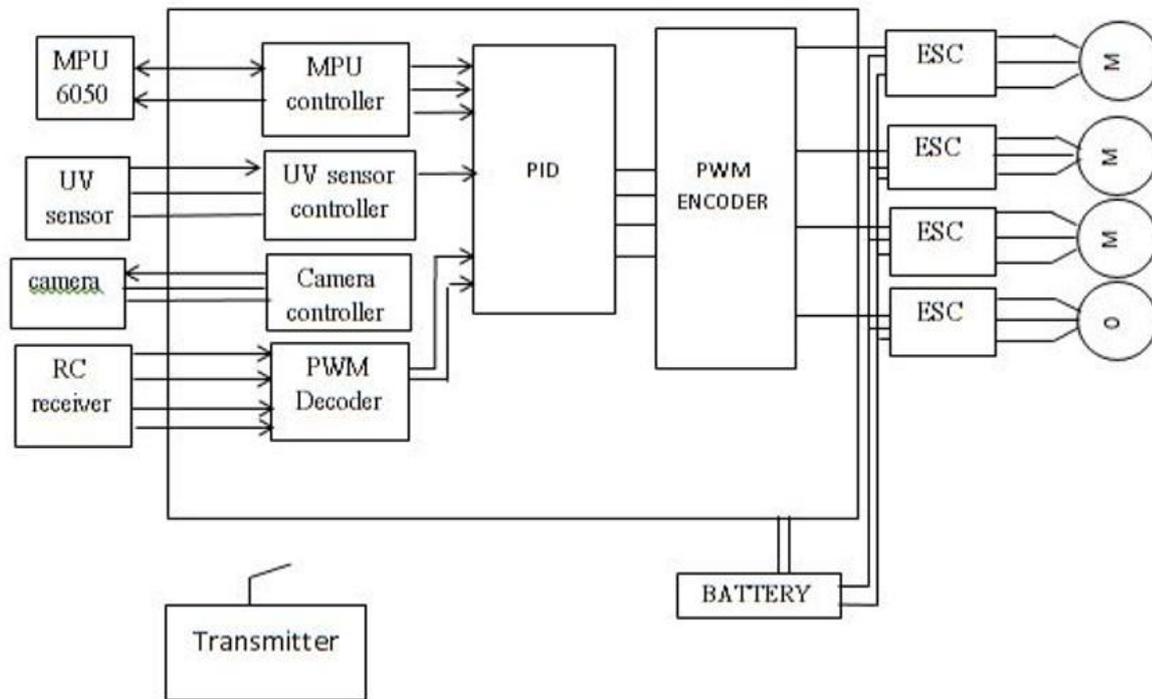
Fig. 1 Block Diagram

The sensor MPU-6050 is used to find theorientation of the craft using accelerometer and gyroscope, it is required to undergo testing and configuration and it requires a complimentary filter to reduce the noise and error produced. then the data and clock signal is connected to the FPGA through the I2C bus, the data is then given to the PID controller which is implemented in FPGA to stabilize and control the quadcopter, it takes the raw data from the MPU-6050 and uses the sensorfusion to get the Yaw, Pitch, Roll(YPR) and minimizes the error to maintain YPR at the set point and the other input to the PID controller is given from the ULTRASONIC sensor which detects the presence of obstacles and sends the signal to the flight controller, PID controller takes the corrective action by generating the corresponding PWM signals to the electronic speed controllers which controls the speed of the motors [4]. The outputs of the flight controller are connected to the electronic speed controllers (ESC's) to which the motors are attached. Besides, RC Receiver is the user input to flight controller, it send the user instruction to the flight controller and commands the Quadcopter to fly in desired motion.

A. PWM ENCODER

1) Esc initialization:

In this process the Maximum and Minimum throttle has to be processed by the ESC, Generally this is done by using the rc receiver, it is connected to the ESC and the maximum throttle signal is transmitted by the transmitter and it is detected by the esc, then it gives a beep now minimum throttle has to be transmitted by the transmitter this is done by moving the throttle gimbal to minimum position.The same process can be done by using a micro controller, it should generate the Maximum and the minimum throttle signals after the minimum signal is detected the esc again gives another beep indicating that minimum throttle has been processed.It has been implemented on FPGA the program is written in Verilog to generate the Maximum and Minimum throttles. The below waveforms shows the results of the simulation.
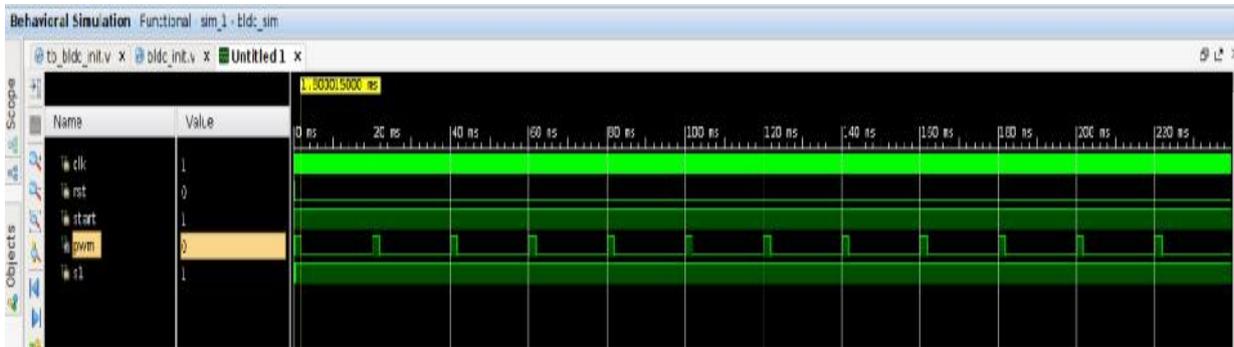
**Fig. 2 Waveforms of ESC Initialization**

2)PWM Signal Generation:

The PWM signal has to be generated to control the speed of the BLDC motors. The ON Pulse should not be more than 2ms and less than 1ms, the time period of the signal has to be maintained as 20ms. The frequency of the signal is 50Hz [2].
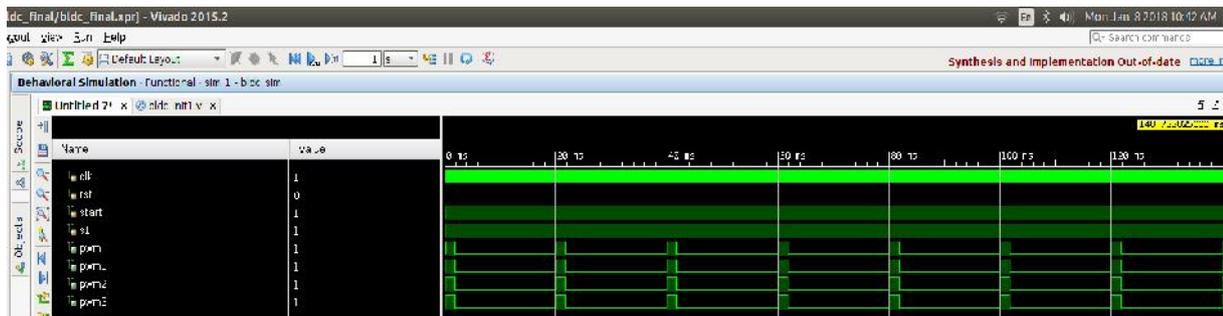
Fig. 3 PWM Signal Generation

B. PWM DECODER:

This module decode the pwm signals from the rc receiver and read the on time period of the each pulse. Similarly it has to do for all the four channels. The waveforms of pwm decoder are shown in Fig. 4.
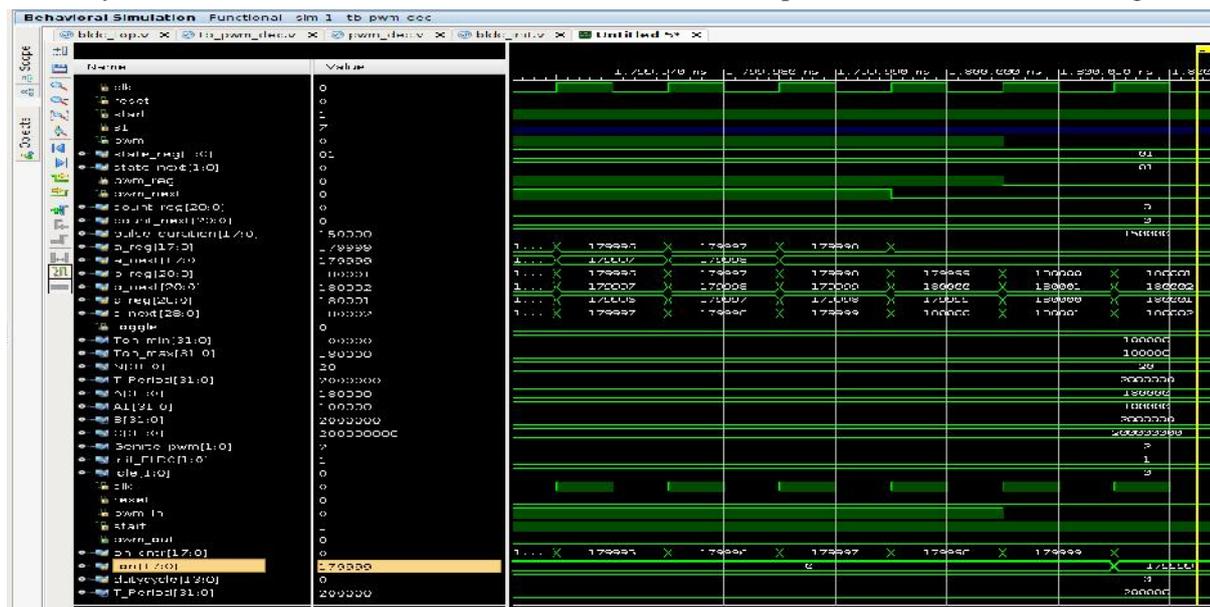
Fig. 4 PWM Decoder

C. MPU -6050 (INERTIAL MEASUREMENT UNIT):

The MPU 6050 is a 6 DOF (Degrees of Freedom) or a six-axis IMU sensor, The MPU 6050 is a sensor based on MEMS (Micro Electro Mechanical Systems) technology. Both the accelerometer and the gyroscope are embedded inside a single chip. This chip uses I2C (Inter-Integrated Circuit) protocol for communication. The MPU 6050 has a built-in DMP (Digital Motion Processor). By enabling the hardware features of this sensor the DMP processes the raw data from the accelerometer and gyroscope to give us the final YAW, PITCH and roll in degrees.[4]

Fig. 5 I2C Interface of MPU 6050 with ZED Board

D. PID Controller

The main challenge is implementing PID. We need two PID controllers for both pitch and roll. The pitch controller will maintain the test stand at a constant angle. The farther you push the pitch gimbal, the farther the platform should tilt. This will require the accelerometer readings from the IMU. The roll controller will maintain the test stand at a constant angle. Thefarther you push the roll gimbal, the farther the platform should tilt. This will require the accelerometer readings from the IMU.[5]

E. MAPPING UNIT

Mapping unit is a module to map the decoded PWM signal from remote control to angles for roll, pitch and yaw command. While throttle is map to percentages value. The below are the formulae for the 4 motors duty cycle at which the motor should rotate.

Motor1 output= Throttle - Roll_required + Pitch_required - Yaw_required.

Motor2 output= Throttle + Roll_required - Pitch_required - Yaw_required.

Motor3 output= Throttle + Roll_required + Pitch_required + Yaw_required.

Motor4 output= Throttle - Roll_required - Pitch_required + Yaw_required.

Fig. 6 PWM Encoder

III. Conclusion

In this work, the objectives achieved are, Designed a FPGA based flight controller of a Quadcopter, established a Quadcopter platform for further study and research purposes and integrated related avionics sensors into the FPGA by designing the communication interface.

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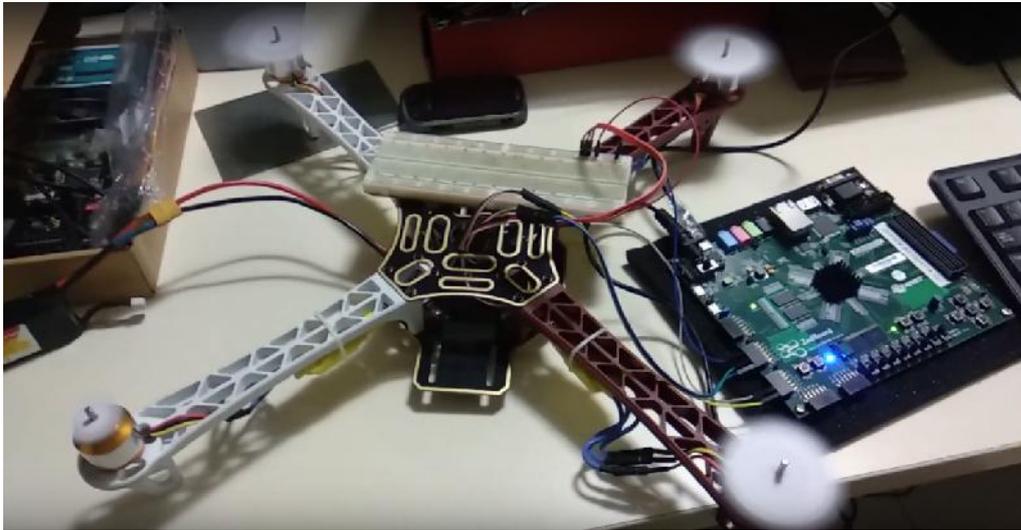
Fig. 8 Motors running with the Zed Board

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