Quad-Copter Using ATmega328 Microcontroller

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Abstract — **This paper presents the design of Quad-Copter flying machine using Atmel microcontroller. The scope of this project involves both hardware design and software implementations. Potentiometer is used as an input device to produce analog signal. The analog signal is converted to digital form using Analog to Digital Converter (ADC) in Atmel microcontroller. The digital value is used by the microcontroller to generate Pulse Width Modulation (PWM) for the Electronic Speed Controller (ESC). ESC is a device that use with Brushless DC (BLDC) motor to control its speed. The project start with literature review where all the information for designing the control system of the quad rotor was gathered. All design requirements was obtained from the literature review. The requirements of the control system of four motor in quad rotor are microcontroller, Electronic Speed Controller (ESC), Brushless DC (BLDC) motors, propellers and the potentiometer as the throttle.**

***Keywords:** Arduino Uno R3; ATmega microcontroller; Electronic Speed Controller; Brushless DC motor.*

I. INTRODUCTION

Quad-Copter, also known as quad-rotor, is a helicopter with four rotors. The rotors are directed upwards and they are placed in a square formation with equal distance from the center of mass of the quad-copter. The quad-copter is controlled by adjusting the angular velocities of the rotors which are spun by electric motors. Quad-copter is a typical design for small Unmanned Aerial Vehicles (UAV) because of the simple structure [1]. Quad-copters are used in surveillance, search and rescue, construction inspections and several other applications.

Conventional helicopter only has one propeller and some helicopter needs a yaw stabilizing rotor at the back of the helicopter. The main propeller not fix to its position since the helicopter need to move forward, backward and turn left or right [2]. It used some mechanism to force the propeller to have an angle of attack on the shaft and spin then the wings start to develop lift force to the helicopter. The mechanism required periodically maintenance in order to make sure the helicopter can perform it desired functions.

II. CONCEPT OF QUAD-COPTER

This quad-copter applied the PWM frequency varying to control the speed of brushless dc motor. There are four main parts that is important in this design including potentiometer as manual controller, ATMEL ATmega328 as the control system, Electronic Speed Controller (ESC) and Brushless DC (BLDC) motor. This Quadcopter uses four propellers, each controlled by its own motor and electronic speed controller. By using a potentiometer we are able to adjust the Revolution Per Minute (RPM) of motor. The Quadcopter platform provides stability as a result of the counter rotating motors which result in a net moment of zero at the center of the Quadcopter [3].

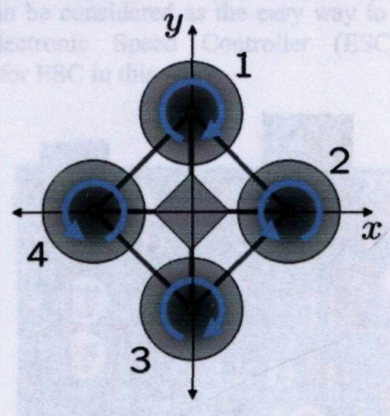


Figure 1: The rotation of propellers

The schematic diagram as shown in Figure 1 is the reaction torques on each motor of a quad-copter aircraft, due to spinning rotors. Rotors 1 and 3 spin in one direction, while rotors 2 and 4 spin in the opposite direction.

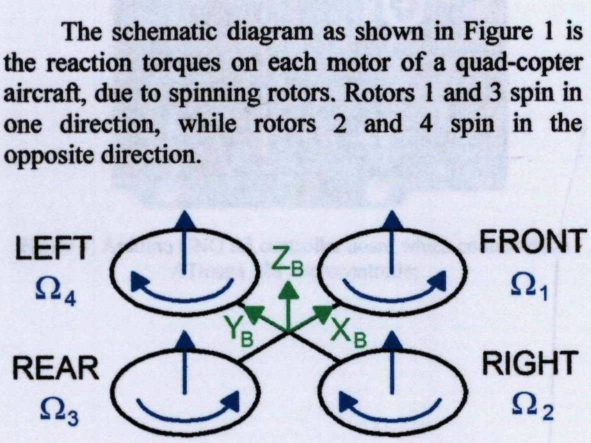


Figure 2: The angular speed of the propellers

The fixed-body B-frame is shown Figure 2 in green and blue are represented the angular speed of the propellers. In addition to the name of the velocity variable, for each propeller, two arrows are drawn: the curved one represents the direction of rotation; the other one represents the velocity. This last vector always points upwards hence it doesn't follow the right hand rule (for clockwise rotation) because it also models a vertical thrust and it would be confused to have two speed vectors pointing upwards and the other two pointing downwards [4].

III. METHODOLOGY

The project methodology was based on the experimental design. Figure 3 shows the flow chart of the overall methods that have been applied throughout the work.

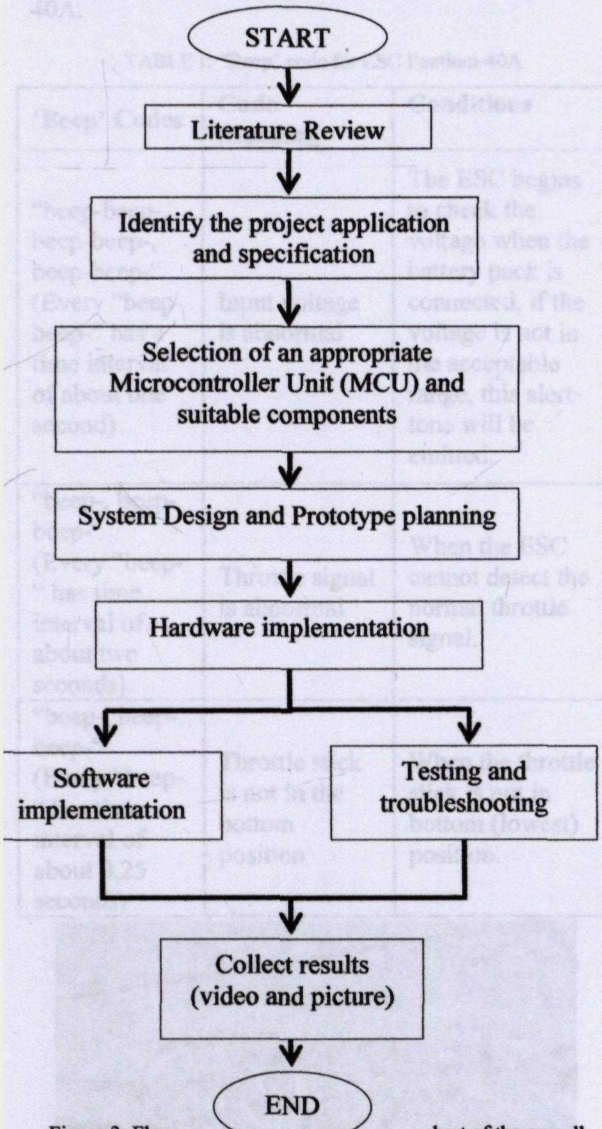


Figure 3: Flow chart of the overall method

Figure 3, shown the flow chart of the development of the project included both hardware and software. The development of hardware and software were divided into two main parts namely the prototype of Quad-Copter and the Arduino UNO R3 controller board. This controller board uses Arduino software to read the PWM signals in C language by using software delay loops technique. This board has 6 PWM port. Therefore, the software delay loops technique was employed instead of built in PWM function because the PWM function only can be accessed from port 3, 5, 6, 9, 10 and 11 of the ATmega328 microcontroller.

IV. HARDWARE DEVELOPMENT

A. *Arduino UNO R3 Controller Board*

Arduino UNO R3 controller board which has a ATmega328 microcontroller as depicted in Figure 4 has been used as the brain or as the Microcontroller Unit (MCU) of the Quad-Copter system. It has 28 pins with available 7 pins to be selected as input and output ports. The port has been chosen for PWM is port 3, 9, 10 and 11. Then for potentiometer is port A0, 5V and GND. The chosen of this Arduino UNO R3 controller board was relying on several factors for instances it is flexible in term of interfacing between the software and hardware development. Besides, this MCU can be considered as the easy way to interface with Electronic Speed Controller (ESC) which suitable for ESC in this work.

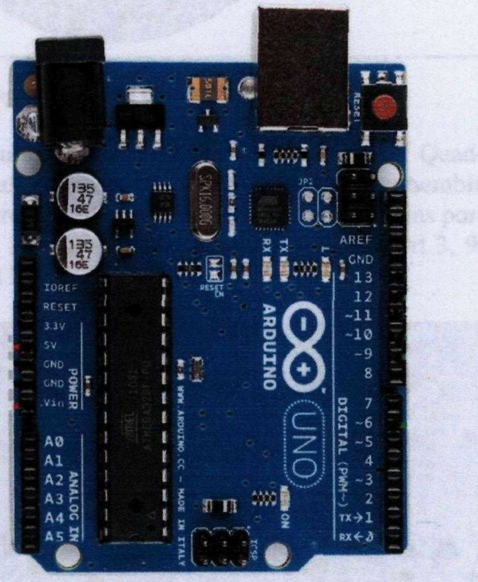


Figure 4: Arduino UNO R3 controller board which comes with a ATmega 328 microcontroller

B. Electronic Speed Controller (ESC)

In this project, four ESC are used to control the speed of four Brushless DC (BLDC) motors based on PWM frequency signal from control system. This device encodes the PWM from microcontroller and produce pulse to the motor to run depending on the frequency of the pulse. The range of the frequency is depends on the type of the motor. The unique feature of ESC is it send signal to the Brushless DC (BLDC) motor to generate 'beep' codes. Each 'beep' codes have the appropriate meanings. The 'beep' code actually is the sound of the vibration of the Brushless DC (BLDC) motor. This project used ESC Pentium-40A [5]. The current specification of the ESC must same or slightly lower than the ideal operating current of the Brushless DC (BLDC) motor. Table I below shows the operation 'beep' code of the ESC Pentium-40A.

TABLE I: "Beep" code for ESC Pentium-40A

'Beep' Codes	Code Meaning	Conditions
"beep-beep-, beep-beep-, beep-beep-" (Every "beep-beep-" has a time interval of about one second)	Input voltage is abnormal	The ESC begins to check the voltage when the battery pack is connected, if the voltage is not in the acceptable range, this alert tone will be emitted.
"beep-, beep-, beep-" (Every "beep-" has time interval of about two seconds)	Throttle signal is abnormal	When the ESC cannot detect the normal throttle signal.
"beep-, beep-, beep-" (Every "beep-" has time interval of about 0.25 seconds)	Throttle stick is not in the bottom position	When the throttle stick is not in bottom (lowest) position.

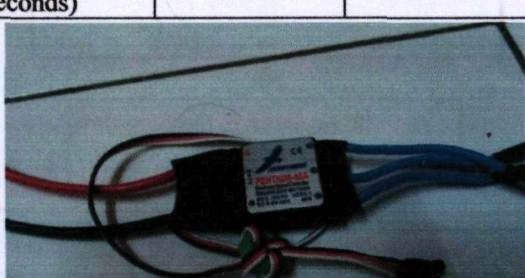


Figure 5: Hobbywing Pentium-40A ESC

C. Brushless DC motor

There are two types of dc motor, brush and brushless dc motor [6]. For this quad rotor design, brushless dc motor is preferred compared to the regular brushed dc motor. The advantages of this motor are it has high thrust that is important in quad rotor design and it also can last longer compared to brushed dc motor. It is due to the rotation of brushless dc motor does not need commutator between the windings and the current conductor. Different with brushed dc motor, brushless dc motor has static core windings and rotating permanent magnet. There are two types of brushless dc motor i.e. with hall sensor and without hall sensor. On sensor type brushless dc motor, hall sensor is used to locate the position of the rotor with the respect of the winding of the stator or core. In sensor less dc motor the position of the rotor is calculated with the back electromotive forces (EMF) using another component or ESC.

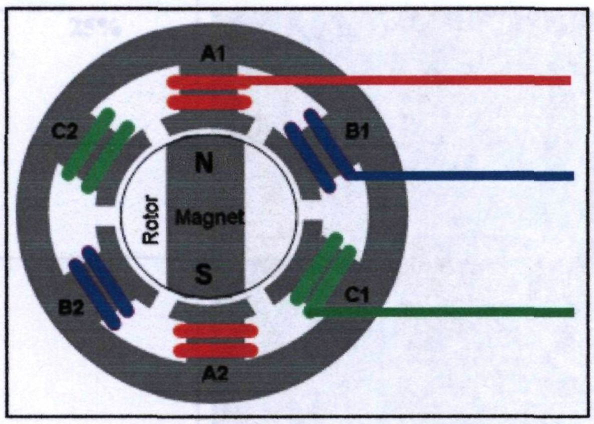


Figure 6: Internal structure of brushless dc motor

Figure 7 shows, the overall harware of Quad-Copter after assemble. This quad-copter assemble with microcontroller Atmega328. By using 4 pins port PWM at Arduino UNO R3 board which is port 3, 9, 10, and 11.

Figure 7: The overall Quad-Copter hardware with Arduino UNO R3 controller board.

Figure 6 shows the overall flow of designing the system.

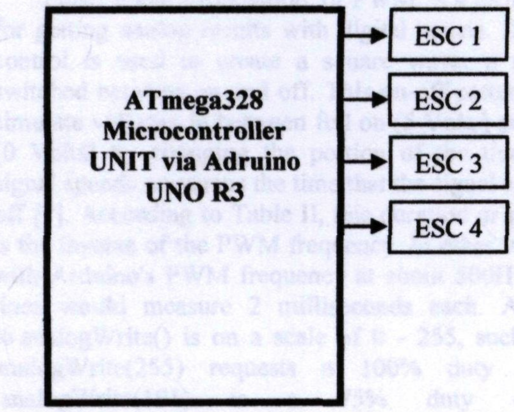


Figure 8: Block diagram of Quad-Copter

V. SOTFWARE DEVELOMENT

The *ATmega328 microcontroller* was programmed with the program execution which needs it to read the analog signal input. The analog signal from the potentiometer converted to digital signal using analog to digital converter that has already implemented in the microcontroller.

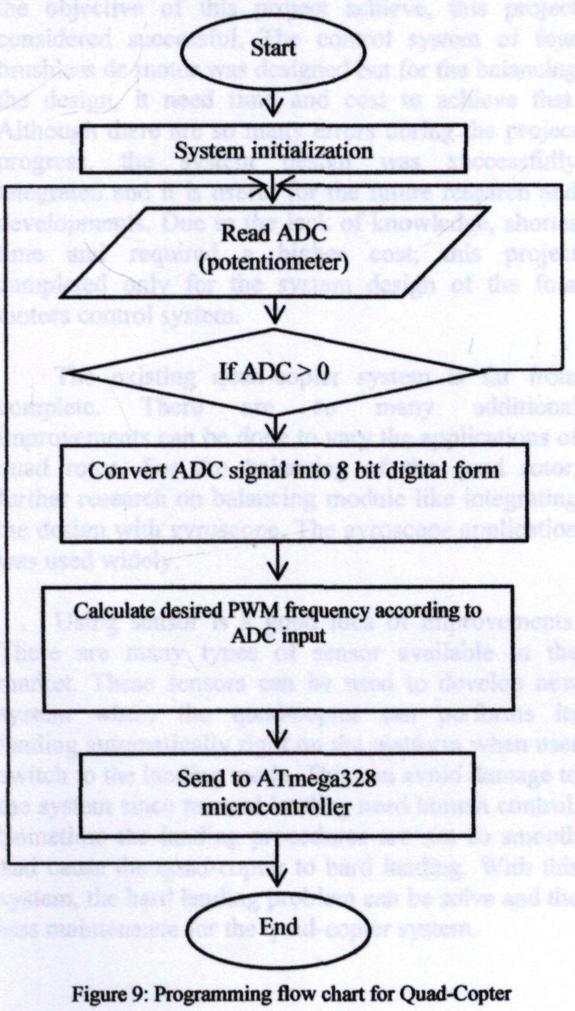
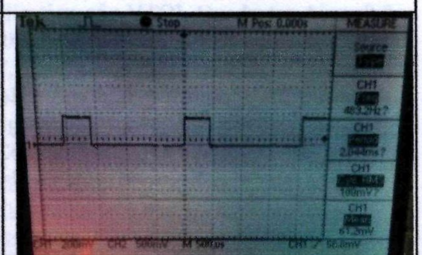
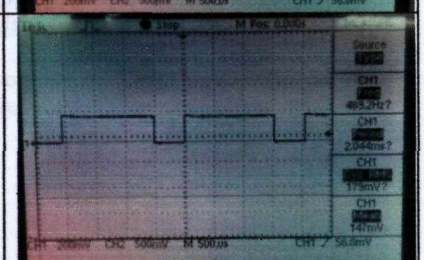
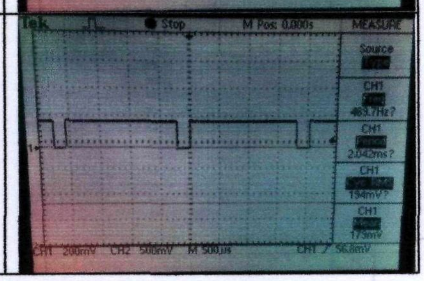


Figure 9: Programming flow chart for Quad-Copter

VI. RESULT

The results of the PWM signals for rotation of BLDC motor were simulated through Arduino software and observed with the aid of an oscilloscope as shown in Table II. The use of the oscilloscope basically to observe the PWM signals and measure its frequency and duty cycle. The frequency should be 50Hz and duty cycle approximately 20ms for every pulse. Table II shows the PWM signals from one of the BLDC motor and ESC ports of the ATmega328 microcontroller were generated using software delay loops technique. These PWM signals were powered with a regulated voltage of 5V from the Arduino UNO R3 controller board.

TABLE II: Results for square wave of Quad-copter observed through an oscilloscope

Percentage of duty cycle	PWM Signal
25%	
50%	
75%	
100%	

VII. DISCUSSION

Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (5 Volts) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off [7]. According to Table II, this duration or period is the inverse of the PWM frequency. In other words, with Arduino's PWM frequency at about 500Hz, the lines would measure 2 milliseconds each. A call to analogWrite() is on a scale of 0 - 255, such that analogWrite(255) requests a 100% duty cycle ,analogWrite(191) is a 75% duty cycle, analogWrite(127) is a 50% duty cycle and then analogWrite(63) is a 25% duty cycle [8].

VIII. CONCLUSION AND RECOMMENDATION

The prototype of this design is only the early stage of quad-copter flying machine system. There are so many improvements need to be done to obtain the better result and further the design application. As one the objective of this project achieve, this project considered successful. The control system of four brushless dc motor was designed but for the balancing the design, it need time and cost to achieve that. Although there are so many errors during the project progress, the system design was successfully integrated and it is useful for the future research and developments. Due to the lack of knowledge, shorter time and required a higher cost, this project completed only for the system design of the four motors control system.

The existing quad-copter system is far from complete. There are so many additional improvements can be done to vary the applications of quad rotor. For the balancing of the quad rotor, further research on balancing module like integrating the design with gyroscope. The gyroscope application was used widely.

Using sensor is a good idea of improvements. There are many types of sensor available in the market. These sensors can be used to develop new system where the quad-copter can performs its landing automatically right on the platform when user switch to the landing mode. This can avoid damage to the system since manual landing need human control. Sometime the landing procedures are not so smooth and cause the quad-copter to hard landing. With this system, the hard landing problem can be solve and the less maintenance for the quad-copter system.

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