

# Design and Implementation of Payload (Camera) Control System for Unmanned Aerial Vehicle

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Further use for UAVs by the military, specifically as tools for search and rescue operations, warrant continued development of UAV technology. Due to attraction of UAV application, its technology and development of the UAV, such as control and guidance, payload development and on board computer system, etc.

This paper is focused on design and construction of payload (camera) Pan-Tilt unit control system for UAV. Servo motors are the main drive components of the Pan-Tilt axes. To drive these motors in moving or rotating smoothly, the key technology is to generate the driving PWM signals. For PWM generation, PIC16F877A was used in this paper. PIC16F877A have built in PWM modules. This paper has just provided a friendly interface to control two axes and the control unit runs in open loop type control only. The system was designed so that while pan axis is limited to angles between -45 deg and +45 deg and tilt axis is limited to -45deg and +45deg.

The system is divided into two sections: ground station or transmitter section and receiver section or the payload of the vehicle. The overall block diagram of the proposed system is shown in Fig. 1. In the ground station, the transmitter input data is user command and it was designed using C# language. Serial communication is used for data communication between PC and PIC16F877A. The PIC reads the user command from personal computer and this

## ABSTRACT

The aim of this research is to design and implement PIC based radio frequency wireless communication system of two axes Pan-Tilt payload camera unit for UAV. Camera is used as a payload and two servo motors are used to adjust the camera positioner in two axes to take the desired photo. User interface program is designed by C# language on personal computer; and serial communication RS232 protocol is used for data communication between personal computer and microcontroller. SONY digital camera is used to take the desired photographs and store recorded data to its memory. Ultra High Frequency band radio frequency wireless transmitter and receiver pairs are used for data communication link between the ground station and the receiver on the vehicle. And they are Amplitude Shift Keying (ASK) type IC and transmission frequency is 433.92MHZ. The (Futaba-S3003) servo motors mounted on the payload are driven by PWM pulse related to the transmitted data from the transmitter in order to get the desire payload (camera) orientation. The control system is based on microcontroller PIC16F877A. The microcontroller CCS C language is used for this control system.

**KEYWORDS:** PIC microcontroller, C Sharp, PWM, RF, Digital Camera, UAV

## I. INTRODUCTION

UAVs may be used for a variety of civilian and military purposes, of which rescue operations in dangerous areas and surveillance may be mentioned as obvious examples. Such aircraft have already been implemented by the military for reconnaissance flights.

command data is sent out to transmitter IC via PIC16F877A. The transmitter section uses a RF Transmitter (KST-TX01) working at 433MHZ to transmit the command data.

In the receiver section, RF receiver receives the transmitted data from the RF transmitter and send to the microcontroller (PIC16F877A). The RF receiver (KST-RX706) extracts the data signal from the carrier frequency. These receiver module outputs is detected by PIC and check it and produce the control signal to run the two servo motors and the camera mounted on the payload to reach the required angular position for Pan-Tilt camera unit.

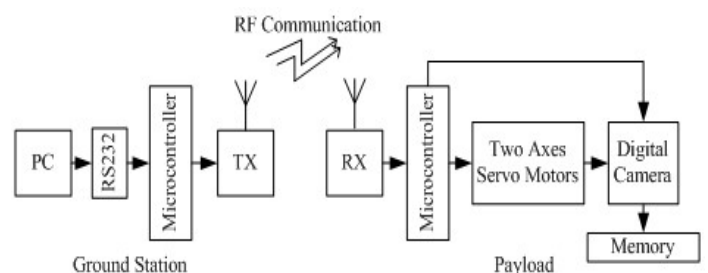


Figure1. Block Diagram of the System

## II. System Hardware Components

The overall system configuration is briefly represented in this section and the hardware used in this research and the physical integration of the components are also described.

**A. PIC Microcontroller**

The PIC 16F877A 8bit microcontroller was chosen to obtain the command data from PC in transmitting section and control the motor on UAV. This microcontroller has a 25MHz processor (the current compiler runs the processor at 20MHz, 33input/output I/O pins, (8k\*14wards) of Enhanced Flash program memory, (386\*8bytes) of RAM, (256\*8bytes) of data EEPROM. The PIC does not have an operating system and simply runs the program in its memory when it is turned on.

**B. Servo Motor (HS-755MG/HITEC)**

This kind of servo motor was chosen according to the following advantages. Fig. 2 shows the typical servo motor.

1. High torque at all speed: (0.23 sec/60degree)
2. Capable of holding a static (no motion) position
3. Able to reverse directions quickly
4. Able to accelerate and decelerate to reach a position



Figure2. Servo Motor

**C. Servo Control**

The servo control board is homemade prototype. The controller is PIC16F877A with two channels PWM signal output. When the width of the square wave equals 1.5 milliseconds, the horn of the servo keeps on neutral (0 degree) position. The width of square wave will change from 1 to 2 milliseconds and the horn of servo will rotate amount -45 to +45 degree as shown in Fig. 4. Fig. 3 shows the ideal of the servo platform structure (Pan-Tilt) camera axes. The axis of servo 1 is parallel to the  $\theta$ -axis of the vehicle and the axis of servo 2 is parallel to the  $\Phi$ -axis of the vehicle.

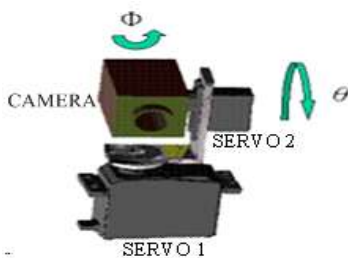


Figure3. The concept of servo platform

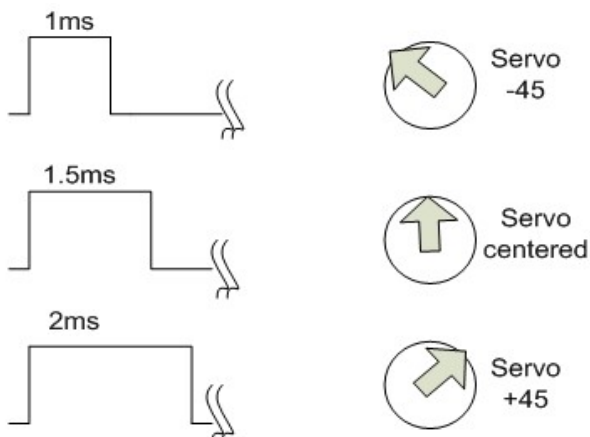


Figure4. Servo are controlled by 1-2ms

**D. Camera Capturing Unit and Camera Modification**

For capturing images, digital camera is connected to receiver circuit on the vehicle and the PIC16F877A microcontroller will trigger the camera capture unit according to user command at the ground station.

For the camera triggering unit, the shutter button includes two pins. The first contact point is a ground wire. The second pin provides the capturing function and once it connects to the ground wire then the camera will take a picture. And the two contact pins are connected with two individual wires and pull out the camera. When the two wires are contacted together, the camera takes one picture. When the wire is released and contacted together again, the camera shutters again.



Figure5. The Modified Camera

For the choice of the camera, the Sony DC-800(8 Mega Pixels) is modified as shown in Fig. 5. The shutter bottom is taking apart from the camera and two contact points are soldered with two wires. The two wires are soldered to the camera to connect a shutter-release board instead of the shutter bottom.

**E. RF Transmitter and Receiver Modules**

For the wireless communication, there are many types of transmitter receiver modules. In this work, KST-TX01/RX706 transmitter and receiver modules are used for data communication between ground station and payload of the vehicle. KST-TX-01 low cost RF transmitter can be used to transmit signal up to 120 meters. These RF Transmitter Modules are very small in dimension and have a wide operating voltage range (3V-5V). KST-RX-706 low cost RF Receiver can be used to receive RF signal from any 433.92MHz transmitter. KST-RX706 is wireless data receive module with VHF/UHF super high frequency.

**F. Circuit Design of the System**

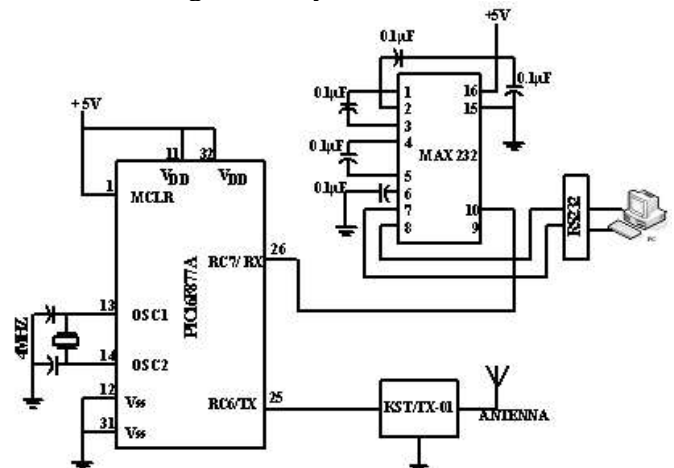


Figure6. Circuit Diagram for Transmitter Section

Overall circuit diagram of payload (camera) control system is shown in Fig. 6 and Fig. 7. PIC16F877A is the main processing unit in payload (camera) control system. In the transmitter section, it mainly contains personal computer, RS232 port, PIC 16F877A, MAX 232 and KST-TX01 transmitter module. The transmitter input data is user command and it was designed using C# language. Serial communication is used for data communication between PC and PIC16F877A. The PIC reads the user command from personal computer and this command data are sent out to transmitter IC via PIC16F877A. The RC6 pin is used to send the data to the RF transmitter.

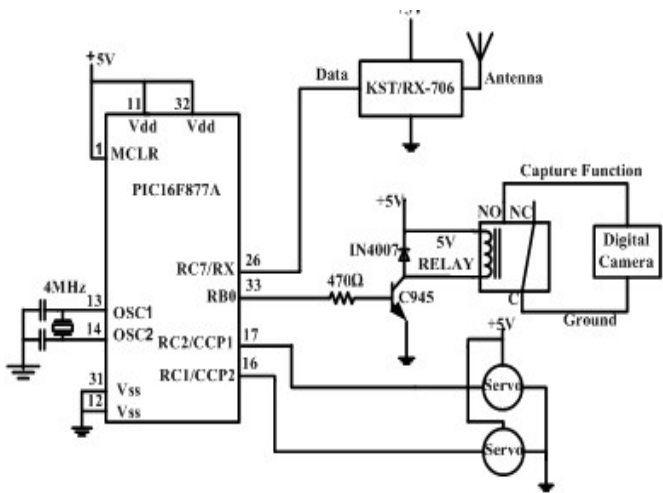


Figure7. Circuit Diagram for Receiver Section

In receive circuit, RF receiver receives the transmitted command data from the RF transmitter and this command data is sent out to the microcontroller (PIC16F877A). These receiver module outputs are detected by PIC and check them and produce the two PWM pulse signal to run the two servo motors to get the required angular position for Pan-Tilt camera unit. For the camera triggering unit, the shutter button includes two pins. The first contact point is a ground wire. The second pin provides the capturing function and once it connects to the ground wire, then the camera will take a picture. C945 NPN transistor is used as a switch to energize 5V relay. RB0 pin output is connected to base of C945 NPN transistor. That causes a collector current passing through the collector and driving the relay which connects to camera being modified.

III. Software Implementation

This section describes the user interface program design and C code that was written to interface the microcontroller with the hardware used in this project.

A. PIC Program Implementation

Fig. 8 shows the program flow chart for transmitter. Firstly, the initialization is started for configuration. The baud rate is set to 1200kbps. Enable serial port and transmission. In the transmitter program, the program reads the user command data from personal computer and these command data are sent out to the transmitter module through the RC6 pin. If the user command data is between the range 1 and 91, the transmitted data will control the Pan-axis channel of camera positioner in receiver section. If the user command data is between the range 101 and 191, the transmitted data will control the Tilt-axis channel of camera positioner in receiver section. If the user command data is 95, the transmitted data will control the camera capturing unit in receiver section.

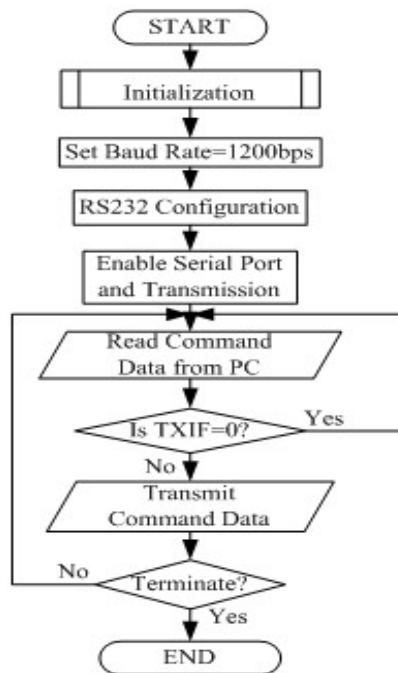


Figure8. The Program Flowchart for Transmitter

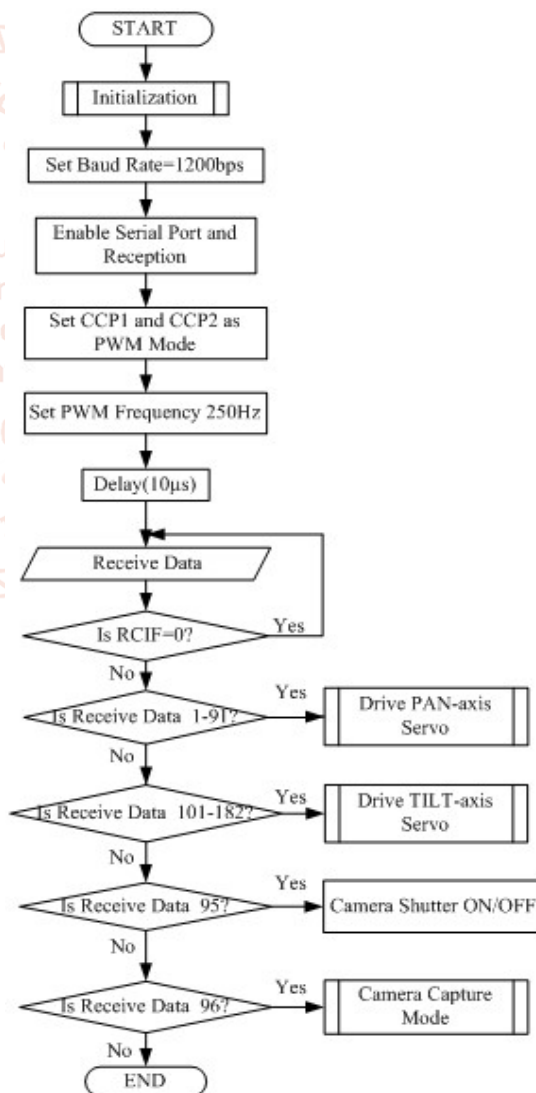


Figure9. The Main Program Flowchart for Receiver

Fig. 9 shows the main program flow chart for receiver. Firstly, the initialization is started for configuration. The baud rate is set to 1.2kbps. Enable the serial port and reception. CCP1 and CCP2 are set as pulse width modulation (PWM) mode for servo motor. PWM frequency is set to 250Hz.

After these configures, delay time (10µs) is used to receive the transmitted command data.

In the receiver portion, the beginning of the program enables the continuous receipt. If the received data is between 1 and 91, the program controls the Pan-axis channel of the camera positioner. If the received data is between 101 and 182, the program controls the Tilt-axis channel of the camera positioner. If the data is 96, the program controls the camera capture mode to take a photo every 5 seconds interval till five pictures are captured. If the data is 95, the program controls the camera shutter On/Off mode.

The baud rate value is specified by writing to SPBRG register. The desired baud rate value can be calculated using the following formula:

$$\text{Baud Rate} = \text{FOSC} / (64 (\text{SPBRG} + 1)) \tag{1}$$

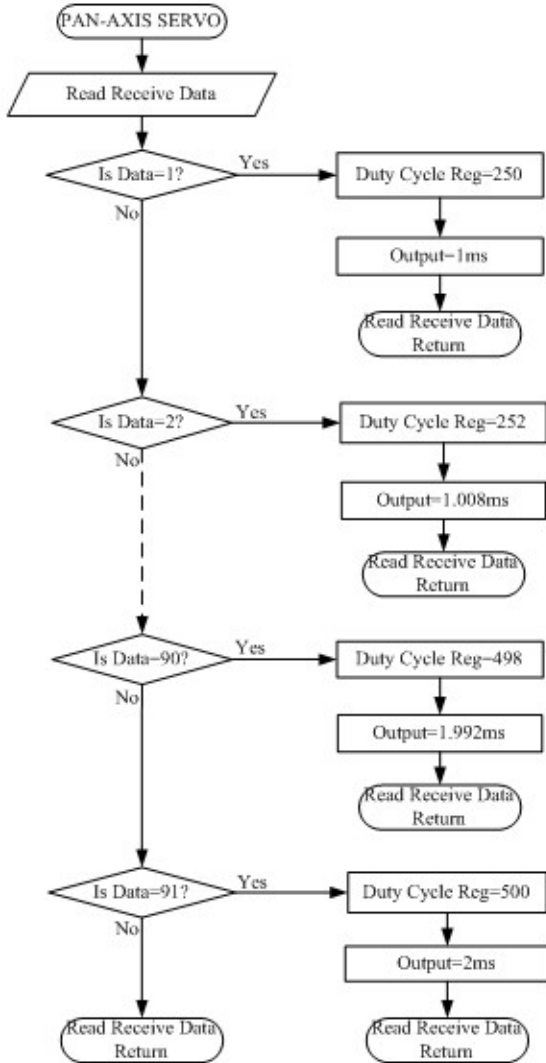


Figure10. Subroutine Flowchart for Pan-axis

PWM signal output interrupt subroutine flow chart to control the payload (camera) positioner for Pan-axis and Tilt-axis is shown in Fig. 10 and Fig. 11. The received command data are user assigned data in the transmitter section. In the receiver section, if the PIC reads the received data '1', the duty cycle value will be 250 and PWM pulse width is 1ms. That PWM pulse drives the Pan-axis servo motor to -45 degree angular positions. If the PIC reads the received data '2', the duty cycle value will be 252 and PWM pulse width is 1.008ms. That PWM pulse drives the servo motor to -44 degree angular positions and so on.

The subroutine flowchart for camera capture mode is shown as Fig. 12. The given baud rate from PIC microcontroller for this RF module is up to 3 Kbps. The baud rate was set to 1.2 Kbps for this project to reduce the error during sending data.

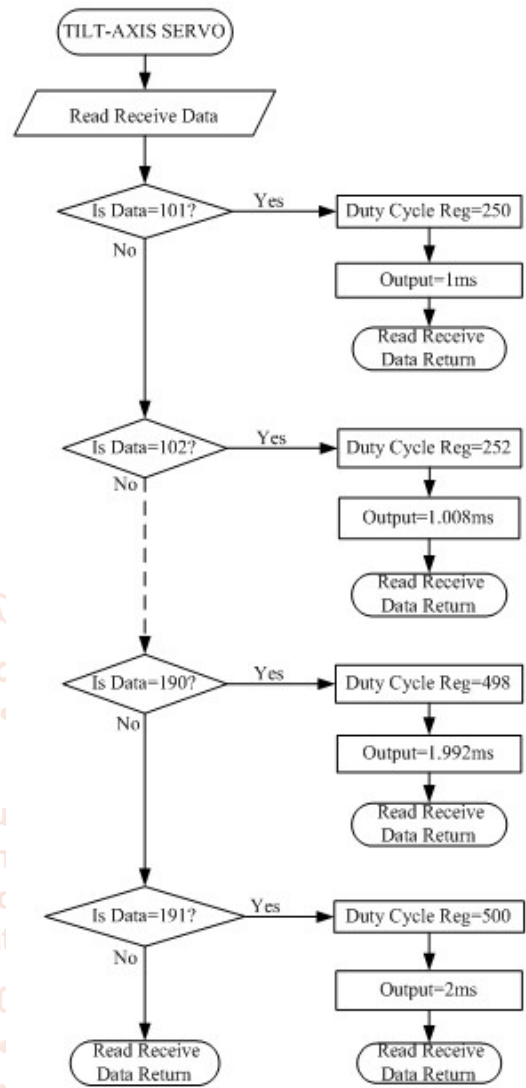


Figure11. Subroutine Flowchart for Tilt-axis

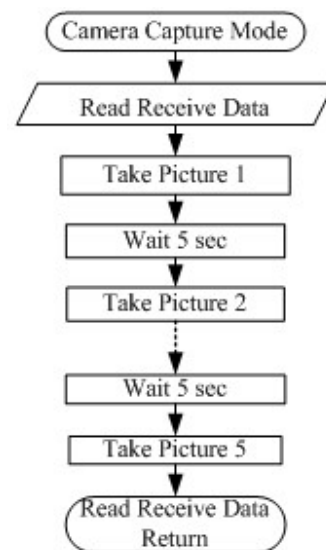


Figure12. Flowchart for Camera Capture Mode

Since selected PIC16F877 clock frequency is 4MHZ, and the selection of baud rate value is 1.2K bps. So, SPBRG value is

$$\text{SPBRG} = \frac{\text{Fosc}}{[64 \times \text{Baud Rate}]} - 1, \tag{2}$$

$$= \frac{4\text{MHz}}{64 \times 1.2 \times 10^3} - 1 = 51$$

So, SPBRG Register value was set to 51 due to 1.2 Kbps baud rate for 4MHz. In this project, PWM mode is used and the following steps configure the CCP module for PWM operation:

The first step is to write the PWM period to PR<sub>2</sub> register. The desired PWM period can be calculated using the following formula:

$$\text{PWM period} = [(PR_2) + 1] \times 4 \times T_{\text{osc}} \times (\text{Timer2 prescaler value}) \tag{3}$$

The proposed system requires the 4ms period and since selected PIC16F877 clock frequency is 4MHz that means T<sub>osc</sub> is 0.25µs and the selection of timer2 prescaler value is 16, PR<sub>2</sub> value is

$$PR_2 = \frac{T_{\text{pwm}}}{4 \times T_{\text{osc}} \times [\text{TMR2ps}]} - 1, \tag{4}$$

$$= \frac{4\text{ms}}{4 \times 0.25\mu \times 16} - 1 = 249 \text{ (decimal)}$$

Second, the PWM duty cycle is established by writing to the DCxB9:DCxB0 bits. The desired PWM duty cycle can be calculated using the following equation:

$$\text{PWM duty cycle} = (\text{DCxB9:DCxB0 bits}) \times T_{\text{osc}} \times (\text{Timer2 prescaler}) \tag{5}$$

The value of DCxB9:DCxB0 bits are calculated by using the following equation:

$$DB9:DB0 = \frac{D_{\text{pwm}}}{T_{\text{osc}} \times \text{TMR2ps}} \tag{6}$$

For 1ms PWM duty cycle that drives the servo motor -45° position, the duty cycle register value is

$$DB9:DB0 = \frac{1\text{ms}}{0.25\mu \times 16} = 250 \text{ (decimal)}$$

For 1.5ms PWM duty cycle that drives the servo motor 0° position, the duty cycle register value is

$$DB9:DB0 = \frac{1.5\text{ms}}{0.25\mu \times 16} = 375 \text{ (decimal)}$$

For 2ms PWM duty cycle that drives the servo motor +45° position, the duty cycle register value is

$$DB9:DB0 = \frac{1.5\text{ms}}{0.25\mu \times 16} = 500 \text{ (decimal)}$$

**Table1. Received Data and Assignment Of Output Data For Tilt - Axis**

Received data	Pulse Width of PWM	Duty Cycle Register value	Degree
1	1ms	250	-45°
2	1.008ms	252	-44.28°
...	...	...	...
46	1.5ms	375	0°
...	...	...	...
90	1.992ms	498	+44.3°
91	2ms	500	+45°

**Table2. Received Data And Assignment Of Output Data For Pan - Axis**

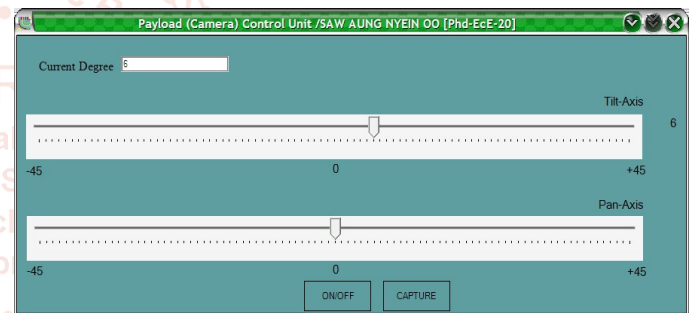
Received data	Pulse Width of PWM	Duty cycle value	Degree
101	1ms	250	-45°
102	1.008ms	252	-44.28°
...	...	...	...
146	1.5ms	375	0°
...	...	...	...
190	1.992ms	498	+44.3°
191	2ms	500	+45°

According to the above procedure, the duty cycle register values are calculated to get the required PWM duty cycle and these values are shown in Table 1 and Table 2.

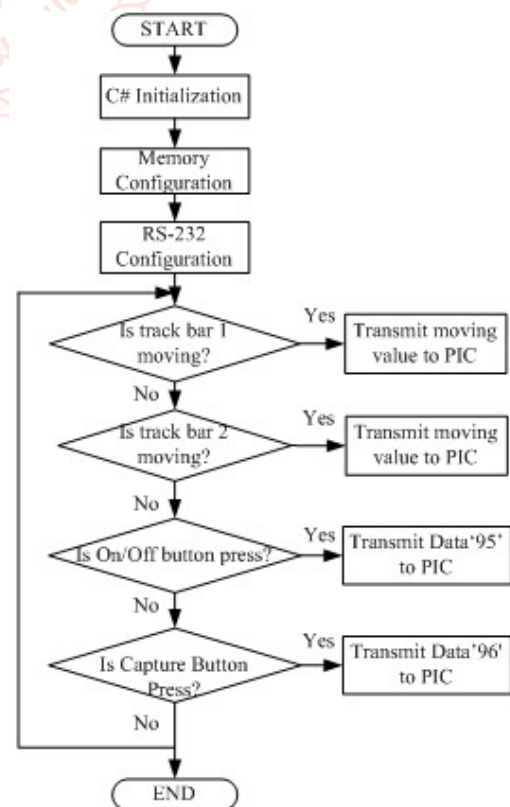
**B. C# Interfacing Software Development**

In this paper, user interface program is designed using C# language. The system is usually open-loop controlled using user controller/camera operator at the ground station. Serial port is used to send the user command data from personal computer to transmitter PIC.

The developed graphical user interface for the proposed system is shown as Fig. 13.



**Figure13. User Interface Window**



**Figure14. User Interface Program Flowchart**

By moving the two track bars at the center of the main screen, user can control the desired servo angle from -45 to +45 degrees with one degree angle resolution. The upper track bar is used to control Tilt-axis camera positioner and the lower one is for Pan-axis camera positioner.

The user interface program flowchart is shown as Fig. 14. At the start of the program, the two track bars are to be checked whether they are moving or not. If the two track bars are moved, the interface program transmits the assigned moving value to transmitter PIC. And then, the program will check the on/off button. If the on/off button is pressed, the program transmits the ASCII code of assigned data '95' to transmitter PIC. After that, the capture button is to be check whether pressing or not. If the capture button is pressed, the interface program transmits the ASCII code of assigned data '96' to transmitter PIC.

#### IV. Experimental Tests and Results

This section describes the oscilloscope displays of the proposed system for two axes camera (Pan-Tilt) unit.

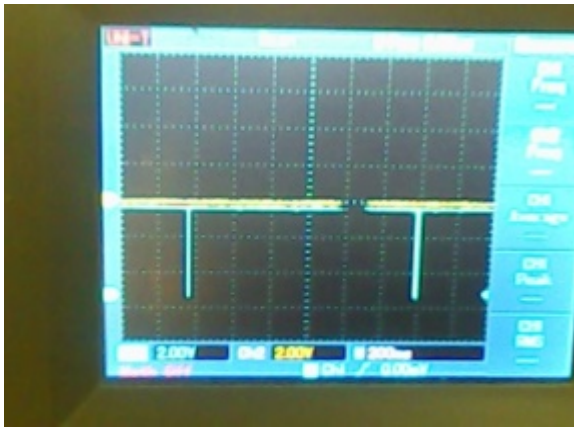


Figure15. Output Signal of Transmitter Circuit

Fig. 15 shows the output signal of transmitter circuit. In the oscilloscope display, the transmitted signal voltage is 4.8V. In Fig. 16, CCP1 channel output of microcontroller is 1ms PWM and that drives the pan-axis servo to -45 degree angle position. CCP2 channel output of microcontroller is 2ms PWM and that drives the tilt-axis servo to +45 degree angle position.



Figure16. 1ms and 2ms PWM Output of Receiver Circuit

In Fig. 17, CCP1 channel output of microcontroller is 1.5ms PWM and that drives the pan-axis servo to 0 degree angle position. CCP2 channel output of microcontroller is 1.984ms PWM

and that drives the tilt-axis servo to -43.2 degree angle position.

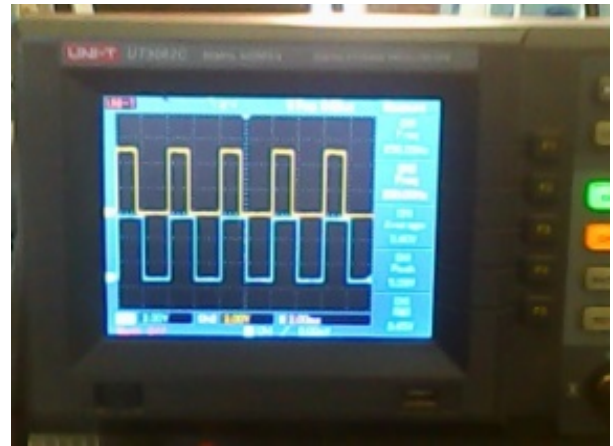


Figure17. 1.5ms and 1.984ms PWM Output of Receiver

In Fig. 18, CCP1 channel output of microcontroller is 2ms PWM and that drives the pan-axis servo to +45 degree angle position. CCP2 channel output of microcontroller is 1ms PWM and that drives the tilt-axis servo to -45 degree angle position.

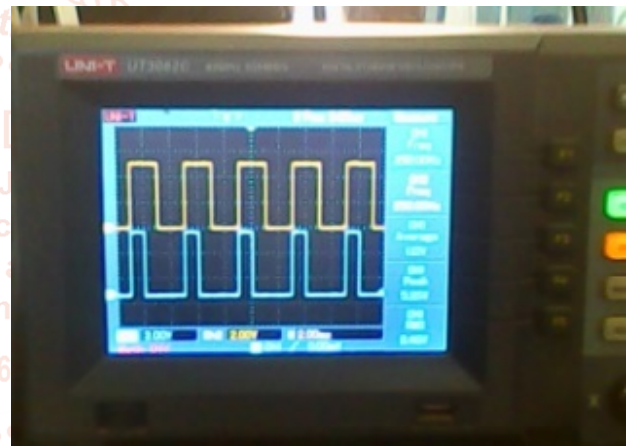


Figure18. 2ms and 1ms PWM Output of Receiver

In Fig. 19, CCP1 channel output of microcontroller is 1.992ms PWM and that drives the pan-axis servo to +44.3 degree angle position. CCP2 channel output of microcontroller is 1.008ms PWM and that drives the tilt-axis servo to -44.28 degree angle position.



Figure19. 1.992ms and 1.008ms PWM Output of Receiver

Fig. 20 shows the recorded photo of overall testing.



**Figure20. Recorded Photo of Overall Testing**

## V. Conclusion

The major goal of this thesis is to design and construct payload (camera) control system of unmanned aerial vehicle for Pan-Tilt unit. There are many types of camera gimbal unit such as Pan-Tilt, Tilt-Roll, Pan-Roll and Pan-Tilt-Roll. Pan-Tilt unit is emphasized in this thesis. The system is usually open-loop controlled using a controller or camera operator at the ground station.

PIC16F877A microcontroller is used as the main controller unit because this microcontroller has built-in PWM modules and USART modules. In the transmitter section, the transmitted signal is operator command data from personal computer and the user interface program was designed by C# language. In this paper, the baud rate was set to 1200kbps to reduce the overrun error in the receiver section during sending data.

## Acknowledgment

The author is greatly indebted to his wife and all of his teachers who have taught him during the whole life.

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