

# The Development of Autopilot System for an Autonomous UAV Helicopter Model

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**Abstract:** This paper presents the design decision and development of autopilot system for an autonomous unmanned aerial vehicle (UAV) helicopter model. The autopilot system designed to demonstrate autonomous maneuver such as take-off, hover and forward flight. The overall system consists of the helicopter with an on-board computer and a second computer serving as a ground station. The flight control is done on-board while mission planning and human user interaction takes place on ground. Sensors used for autonomous operation include acceleration, magnetic field, and rotation sensors (Attitude and Heading Reference System) and ultrasonic transducers. The hardware and software used to autonomously pilot the helicopter are described in detailed in this paper.

**Keywords:** Autopilot System, Autonomous.

## 1. Introduction

Unmanned Aerial Vehicle (UAV) are remotely piloted or self-piloted aircraft that can carry cameras, sensors, communications equipment or other payloads. They have been used in a reconnaissance and intelligence-gathering role since the 1950s, and more challenging roles are envisioned, including combat missions. The UAV have a wide range of applications mostly in military for recognition, environmental observation, maritime surveillance and mine removal activities. The UAV can be also used in non military application such as aerial photography, surveillance, pipeline and utility line inspection and convoy escort. One of the main goals of this research project is to develop and design a reliable accuracy autopilot system for UAV helicopter. The vehicle platform should be integrated with proper hardware and software so that the vehicle can perform the desired autonomous maneuvers.

## 2. Overview of Autopilot System

Every detail of the autopilot system has been carefully optimized with respect to weight, power consumption and capability during system development. There are two connections between the ground and the on-board system consists of standard remote control system operated by a human pilot and a ground station system. The standard remote control system serves as a backup in case the autopilot fails and it is also very useful in the process of controller design. Numerical identification of the helicopter model can be performed by logging the sensor signals as well as the control signals originating from remote control. The communication modules also can be used to control some logical states and controller settings from ground. An overview of the autopilot system is shown in Fig. 1.

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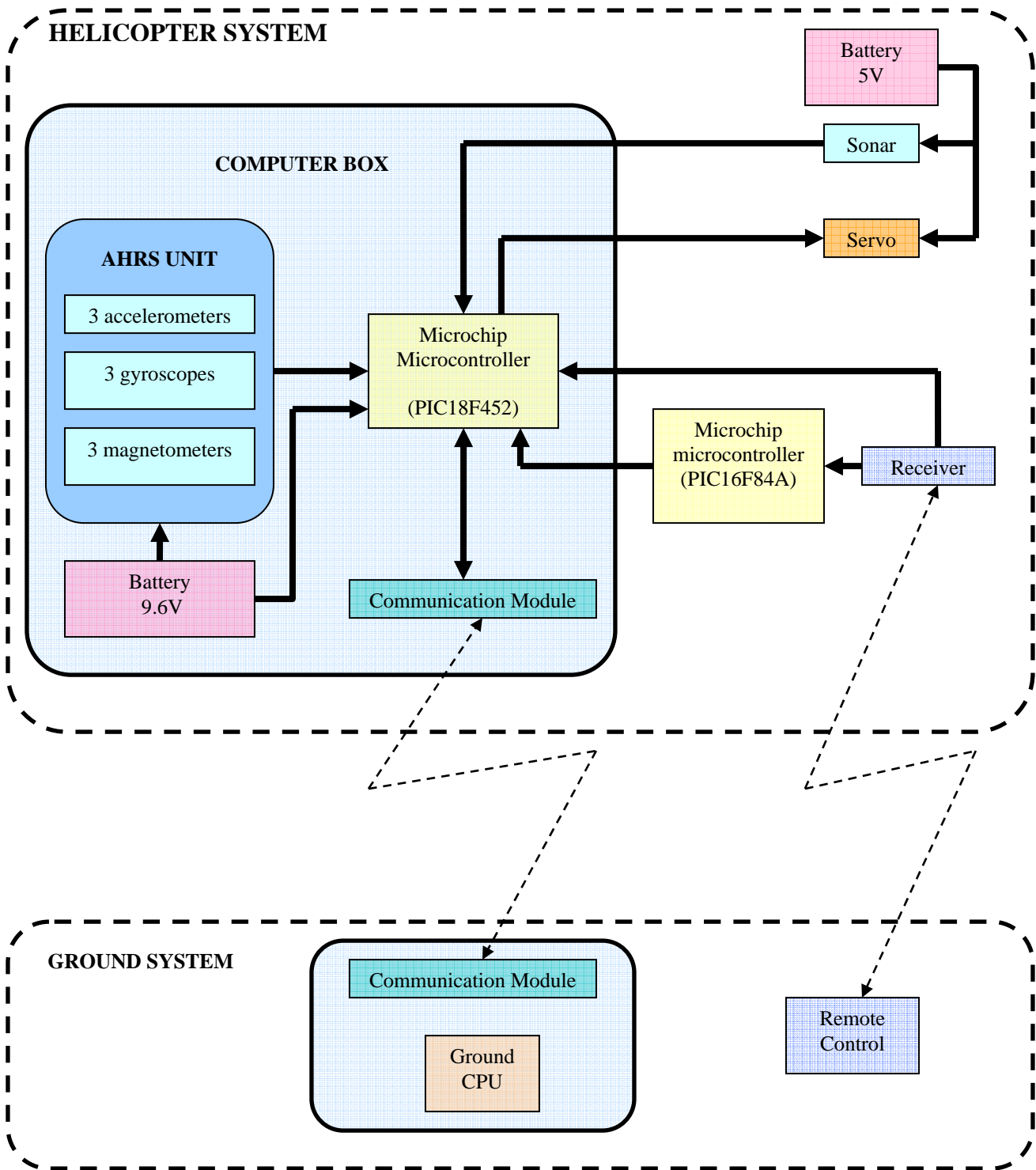


Figure 1 Overview of autopilot system developed.

### **3. Air Vehicle Descriptions**

The basis of the UAV platform is a conventional model helicopter with a rotor diameter of 1.605m and powered by a two-stroke petrol engine which produce power about 15kW. The UAV platform has an empty weight about 4.7 kg and capable to carry about 3 kg payloads with an operation time of 15 minutes.

In order to perform both manually controlled flight and automatic flight control, the tail rotor control signal is fed through a conventional piezo-electric gyroscope as used in most radio controlled helicopter models today. This gyro module adds its controller output to the input originating from the RC receiver or in autonomous flight, the microcontroller. Detailed helicopter parameters and control system design can be found in [1] and [2]. Fig. 2 shows a view of the fully equipped UAV in flight.

### **4. Computers**

All devices on-board are connected to the on-board computer which is a single Microchip PICmicro microcontroller. The ground station consists of a single laptop PC running under Window® operating system which serves as mission control system. The on-board computer is a 40 pin microcontroller which provides 16K instruction space, 256 bytes of variable memory and capable of processing 10 million instructions per second (MIPs) with 10 MHz external oscillator. The PICmicro microcontroller is Flash based which means that it can be erased and reprogrammed without an ultraviolet light source and can be reprogrammed using a simple programmer circuit.

### **5. Microcontroller Programming Overview.**

Programming the microcontroller is a simple three steps process: write the code, compile the code and upload the code into the microcontroller. In this research, code writing and code compilation were done using PicBasic PRO Compilers. The PICBasic Pro Compiler IDE screenshot is shown in Fig. 3 and more detailed information can be found from microEngineering Lab's manual in [3].

The flowchart for the autopilot programming can be viewed in Fig. 4. The flowchart shows the flow of instruction execution made in performing automatic attitude stabilization and manual-automatic control switching in helicopter roll channel. The flowchart can be separated mainly into 4 parts consisting initiate, switching, testing and execution stage.



Figure 2 The unmanned aerial vehicle in flight.

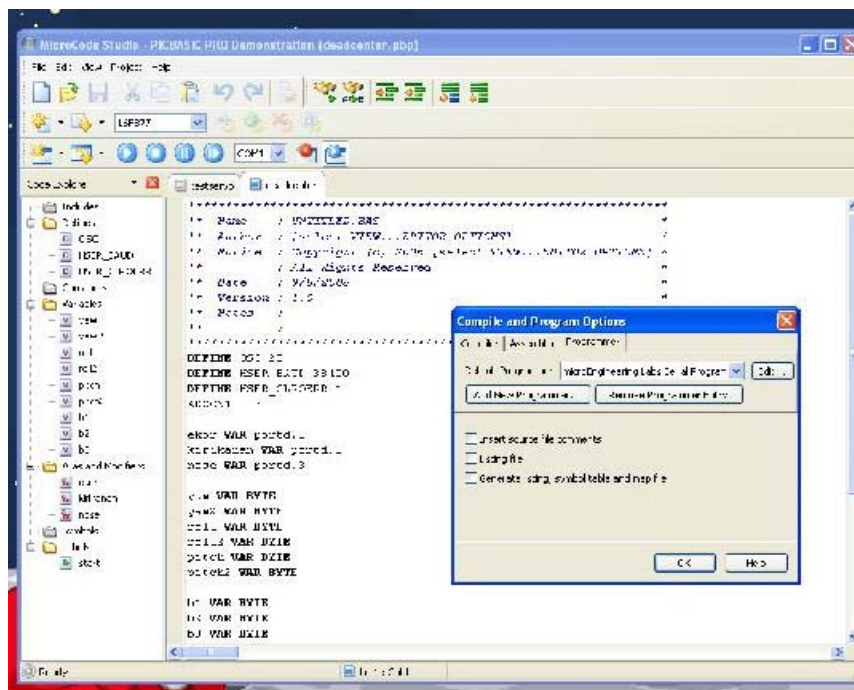
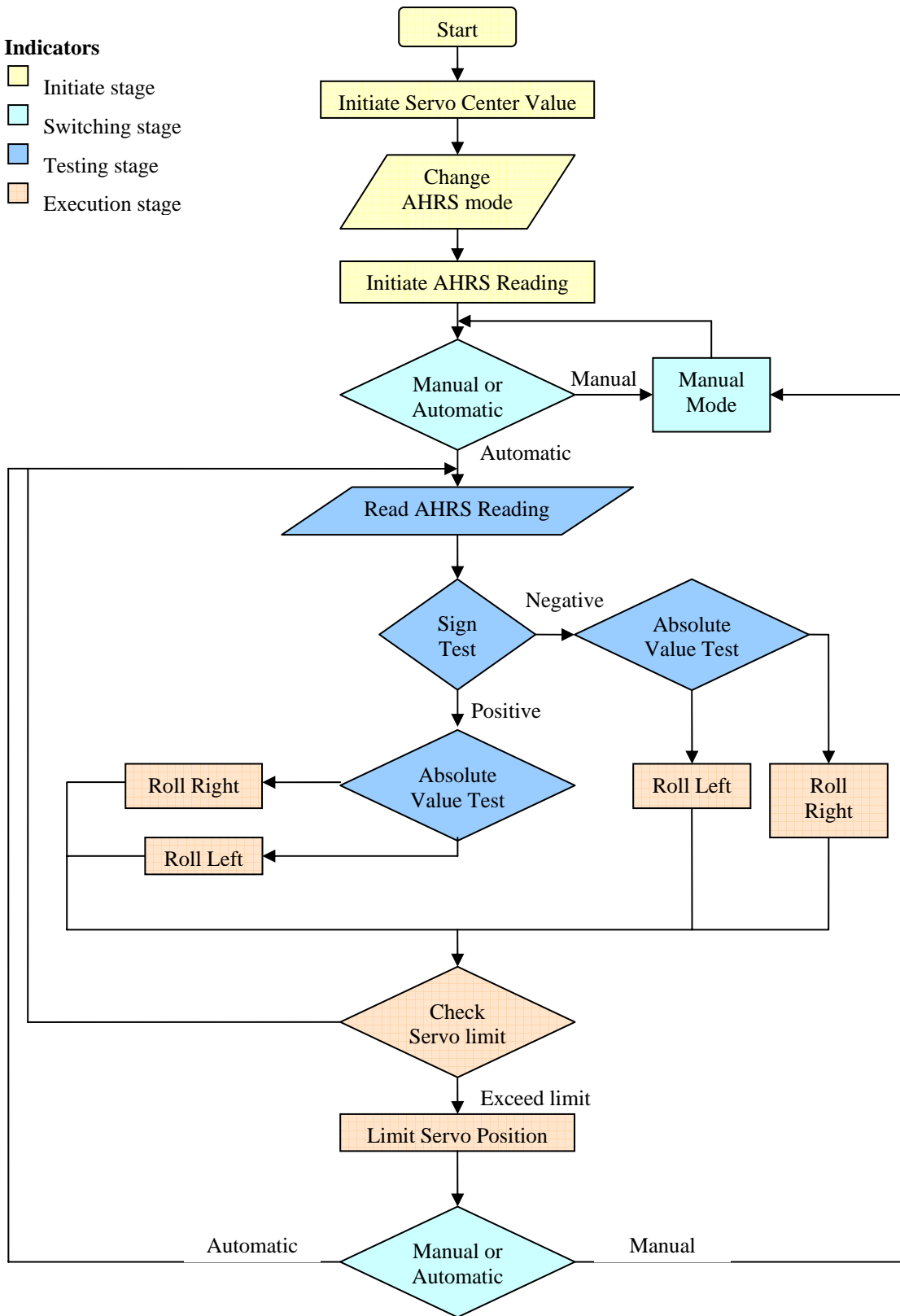


Figure 3 Screen shot of PicBasic Pro Compiler IDE.

**Indicators**

- Initiate stage
- Switching stage
- Testing stage
- Execution stage



**Figure 4** PicBasic Pro programming flowchart.

## 6. Sensors.

Avionics system sensors are needed to collect information on how the aircraft and control system is performing. Three major sensor systems are needed for a basic UAV flight control avionics package i.e. the attitude and heading system, the position and velocity system and the altitude system. These three sensor systems are needed to measure the basic states of the aircraft required for flight control. Due to limitation in our research funding, the Global Positioning System (GPS) for position and velocity determination cannot be implemented into our avionic system since the respective costs were too expensive.

Attitude determination of a UAV is critical in order to ensure maintained flight for the autopilot system developed in this project. An Attitude Heading Reference System (AHRS) has been selected for UAV attitude measurement using Rotomotion low-dynamics Attitude and Heading Reference System (AHRS) which consists a six degree of freedom inertial measurement unit (6-DOF IMU) and a three axis magnetometer for heading measurement. The Kalman filter used in this product will track 16 states consists of Euler angles ( $\phi, \theta, \psi$ ), orientation in quaternion ( $q_0, q_1, q_2, q_3$ ), angular rate or gyro biases ( $p, q, r$ ), magnetic fields ( $m_x, m_y, m_z$ ) and accelerations ( $a_x, a_y, a_z$ ). Fig. 5 shown the view of AHRS used.



**Figure 5** The low dynamic AHRS (AHRS3050AA) from Rotomotion, LLC. This AHRS operated at slower updated rated (30Hz) and output the attitude measurement via serial port compare to other high end AHRS from Rotomotion, LLC.

The final component is the altitude measurement system. The Polaroid 6500 sonar ranging module (Fig. 6) has been chosen to determine the altitude data for this project. This module, with a simple interface, is able to measure distances from 6 inches to 35 feet (0.1524m to 10.668m). The typical absolute accuracy is  $\pm 1\%$  of the reading over the entire range.

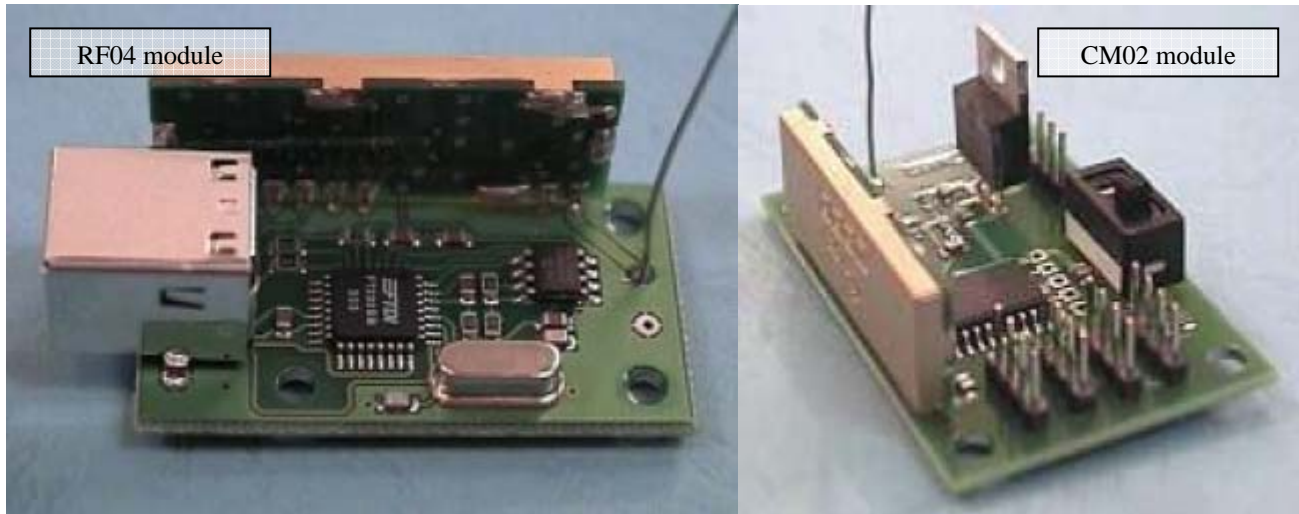


**Figure 6** The Polaroid 6500 Ranging module.



## 7. Communications.

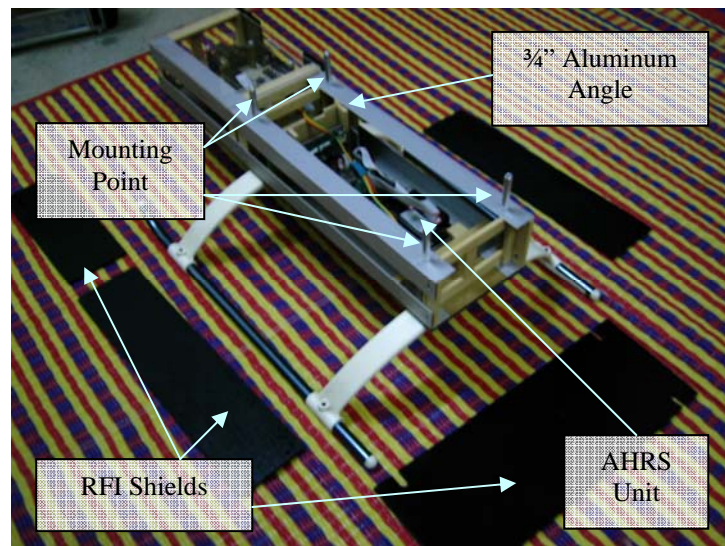
Communication between helicopter and ground station is performed via wireless data link from LPRS EasyRadio ER400TRS module which operates at 433-4MHz. The CM02 module, together with its companion RF04 module forms a complete interface between onboard computer and ground station. Commands can send down to helicopter onboard computer and receive telemetry data back up to the ground station computer. Fig. 7 shows both telemetry pair used in the research project.



**Figure 7** The RF04 and CM02 modules used in the research project.

## 8. System Integration

The complete autopilot system integration with the helicopter had been done after all the electronics were built and installed considering several factors such as power requirement, mounting, electromagnetic and radio interference. Fig. 8 shows photo of the integrations being done. In order to have a computer control the vehicle, it is necessary to interface to the remote control equipment on the vehicle. A manual to automatic switch is used for testing and safety of the helicopter. In order to allow for manual override of computer control, a switch box was designed. The pulse width decode is done on single Microchip microcontroller and the connection between the standard RC equipment is illustrated in Fig. 9.



**Figure 8** The avionics box design and the mounting points to helicopter frames.

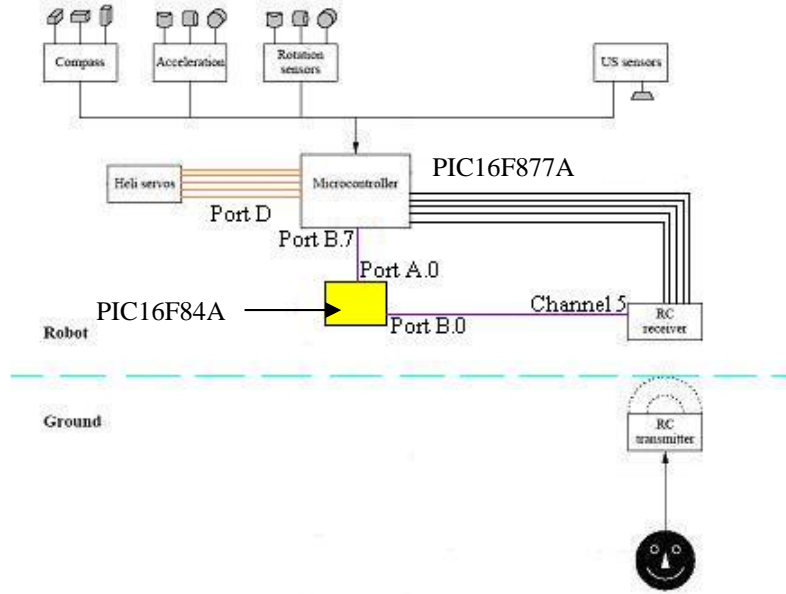


Figure 9 Manual to automatic switch connections.

## 9. Conclusion.

The paper has presented the design and development of autopilot system for UAV helicopter model using on-board computing and has been successfully tested for hovering flight. Low cost sensing equipment used for the helicopter distinguished this project from others which use more expensive inertial and altitude measurement modules. The stabilization of helicopter heading, pitch, roll and altitude has all been successfully demonstrated and this shows the possible achievement towards the development of autonomous UAV.

## 10. Acknowledgements.

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