Hardware System Design of Quad-rotor Aircraft Based on STM32F103

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Abstract. The paper outlines the configuration and the hardware system architecture of the quad-rotor aircraft, describes the overall design of the hardware system of the quad-rotor aircraft, expounds the design method of each subsystem of the hardware system of the quad-rotor aircraft, and finally gets the complete hardware system of the quad-rotor aircraft by joining the design results of subsystems.

Introduction to Quad-rotor Aircraft

The quad-rotor aircraft is also known as the quad-rotor helicopter. Its body is a cross bracket. There are a flying control computer and some external equipment on the middle part of the bracket. There are four motors installed on four tips of the bracket, and four propellers are directly connected with the motors respectively. The propellers which have the same structure and radius are in the same plane and provide the power to the aircraft.

The traditional helicopter is equipped with a main propeller and a tail propeller. The helicopter controls its posture and position by changing the angles of the propellers. Unlike traditional helicopters, the quad-rotor aircraft controls its posture and position by changing the speed of four motors. The quad-rotor aircraft is a vertical takeoff and landing machine with six free degrees. It has six kinds of output status and only four input forces, so it is an under actuated system.

The quad-rotor aircraft is suitable for monitoring and reconnaissance in the near ground environment, such as indoor, urban and jungle, and has a broad application prospect. It has great attraction for the vast number of researchers because of its novel appearance, simple structure, low cost, excellent performance and unique flight controlling technology, so it has become a new research hotspot in the world [1,7].

At present, there are a lot of successful commercial cases of quad-rotor aircraft in the world. A lot of companies, universities, research institutes have made considerable progress on quad-rotor aircraft design, manufacture, control and application. The function and cost performance of quad-rotor aircraft increase year by year, and a variety of new, singular, intelligent quad-rotor aircraft emerge ceaselessly [2]. It can be predicted that more and more researchers and engineers will join in the research of quad-rotor aircraft, and more quad-rotor aircrafts will be designed and produced in the near future.

The design, manufacture and debugging process of quad-rotor aircraft involves many disciplines such as pattern recognition, sensing, electronics, communication, control, computer, machinery, power supply, and so on. It is a complex system engineering which requires a combination of knowledge and technology of many disciplines. Generally speaking, the design of the quad-rotor aircraft includes hardware system design and software system design. This paper focuses on the design method of the hardware system of the quad-rotor aircraft.
The Overall Design of Hardware System of Quad-rotor Aircraft

The Configuration of Quad-rotor Aircraft

The configuration of quad-rotor aircraft is shown in figure 1. Motor 1 and motor 3 rotate anti-clockwise while motor 2 and motor 4 rotate clockwise. The reverse torque exerted by each rotor on the fuselage is opposite to the rotation direction of the rotor, so such configuration can balance the reverse torque of the rotor to the fuselage [3]. When the aircraft is running, the gyroscopic and aerodynamic torque effects of each rotor counteract each other so that the aircraft can fly steadily.

The Architecture of Hardware System of Quad-rotor Aircraft

The hardware system of the quad-rotor aircraft includes power management module, height information detection module, posture information detection module, data processing module, remote control module and motor control module [4]. We integrate these modules according to the function of modules and divide the hardware system of aircraft into four subsystems: power subsystem, information collection subsystem, data processing subsystem and motion control subsystem [5,6]. The architecture of the hardware system of the quad-rotor aircraft is shown in figure 2.
Subsystem Design of Quad-rotor Aircraft

Power Subsystem

The power supply of the quad-rotor aircraft comes from a rechargeable battery of which the rated output voltage is 3.7V and the electricity is 350mAh. Since each module has different requirements for power supply, especially for different voltages, different voltage regulator chips are needed to distribute different voltages for different modules. The power subsystem of the quad-rotor aircraft is shown in figure 3.

![Figure 3. The power subsystem of the quad-rotor aircraft.](image)

The working voltage of MCU STM32F103, barometric sensor MS5611, 6 axis gyroscope and accelerometer MPU6050 is 3.3V, which requires stable power supply to avoid interference generated by motor operation. In order to meet the requirements of these chips, first of all, the regulator LM27313 takes power from the battery and outputs 5V source; then, the regulator MIC5205 takes power from LM27313 and outputs 3.3V source, which can supply power for STM32F103, MS5611 and MPU6050.

The working voltage of bluetooth module is 5V. Since the regulator LM111 of bluetooth module can turn 5V to 3.3~6V, the regulator MIC5205 can take power from LM27313 and output 5V source. We use pin20(PB2) of STM32F103 to control bluetooth module.

The motor needs high-power power supply which should be low internal resistance, high current and stability, so it can directly pick up electricity from 3.7V battery.

The circuit schematic diagram of the power subsystem of the quad-rotor aircraft is plotted according to above design idea, as shown in figure 4.
Information Collection Subsystem

**Aircraft Posture Information Detection Module.** The normally running aircraft should be able to maintain the hover state and to move forward and backward, left and right in the air, therefore, the aircraft must be able to judge its posture for MCU to control it according to its current posture and next action or state.

We use chip MPU6050 which integrates a 6 axis gyroscope and an accelerator as the posture information detection sensor. MPU6050 communicates with MCU STM32F103 through I2C. Pin12(INT), pin23(SCL), pin24(SDA) of MPU6050 are connected to pin41(PB5), pin42(PB6), pin43(PB7) of STM32F103 respectively. The interface circuit of MPU6050 is shown in figure 5.
**Aircraft Height Information Detection Module.** The normally running aircraft should be able to measure its real-time height in the air, and send the height information to MCU to control the aircraft. As you know, the altitude corresponds to the barometric value in the certain range of the earth's surface. The altitude of a point can be calculated only if the barometric value of the point is measured. We use barometer chip MS5611 as the height information detection sensor. The interface circuit of MS5611 is shown in figure 6.

**Data Processing Subsystem**

We use STM32F103C8T6 as the core control chip. The highest frequency of the MCU is 72MHz. The MCU has 32 bit CPU, 64KB flash program memory, 20KB data memory, 3 general timers, 1 high-grade timer, 2 SPI communication interfaces, 2 I2C communication interfaces, 3 USART communication interfaces, 1 USB communication interface, 1 CAN bus interface, 2 modules of 10 channel 12 bit synchronous ADC, 1 module of 8 channel pulse width modulation and 37 digital I/O ports. The interface between the MCU and other peripherals is shown in figure 7.
From figure 7, we can see that the I/O ports of STM32F103C8T6 are used as follows: PA0~PA3 output PWM signals to control four motors; PA9 and PA10 are used as USART1_RX and USART1_TX of BLUETOOTH or USB; PB6 and PB7 are used as I2C_SCL and I2C_SDA of MPU6050 module; PB8 and PB9 are used as SCL and SDA of MS5611 module.

Motion Control Subsystem

Motor Control Module. We use Schottky diode BAT54C and MOSFET to design the motor-driving circuit. PA0~PA3 of MCU output PWM controlling signals to four motors. The driving circuit of motor 1 is shown in figure 8, and the other three motor-driving circuits are alike.

Figure 8. The driving circuit of motor 1.

Remote Control Module. The remote controller is used to control the movement and state of the aircraft. The remote controller communicates with the aircraft through the BLUETOOTH module. The receiving and sending pins of the BLUETOOTH module are connected to PA9 and PA10 of STM32F103C8T6 respectively. The interface circuit of the BLUETOOTH module is shown in figure 9.

Figure 9. The Interface Circuit of the Bluetooth Module.

Summary

Combining the design results of each subsystem, a complete hardware system of the quad-rotor aircraft is obtained. It must be explained that the quad-rotor aircraft system includes hardware system and software system, and this paper just introduce the design method of the hardware system. Obviously, the quad-rotor aircraft only with the hardware system cannot fly without the corresponding software system. Therefore, we need to design the software system of the aircraft after designing the hardware system. Due to limited space, this article does not introduce the program design method and we shall expound in another page.

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