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Original Research Article

A Design of Spherical Unmanned Aerial Vehicle Based on ARM

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Abstract: At present, the application of unmanned aerial vehicle (UAV) is widely used in daily life, but it can easily lead to destruction if the UAV once out of control. Based on ARM processor, we design a three-rotor rotorcraft with a spherical appearance. The rotor and other components of the aircraft are placed inside the shell, which played a good protection for the UAV. The corresponding hardware and software are designed so that the UAV can realize the following functions, such as automatic and manual flight, with good maneuverability and crashproof performance. This design can maximize the prevention of UAV crash and meet the design requirements, which is relatively a new form of UAV.
Keywords: Spherical UAV, ARM, Rotorcraft, Crashproof.

INTRODUCTION

With the rapid development of science and technology and new materials, UAV has been widely used in military, agricultural and so on, and has become a research hotspot [1]. At present, most of the UAVs are rotor type, such as four-rotor aircraft and six-rotor aircraft [2], but most of the UAV rotors are exposed to outside, so the UAV rotor may encounter various damage, the UAV with damaged rotor will lose balance then led to crash. Therefore, the anti-collision performance of UAV is a key research content, and spherical shape design is a better anti-collision design of UAV. Based on the ARM controller, a UAV with a spherical shape is designed. The experimental results show that the UAV has good flight performance and can meet the design requirements.

OVERALL DESIGN OF THE UAV

The UAV is spherical appearance, using batteries as the power supply. The UAV can safely take off and land, during the flight, it can achieve vertical flight, hovering and steering. The spherical structure ensures the safety of the rotor and its internal structure to achieve the desired function.

Design Requirements

The UAV needs to meet the following requirements:

A. Can effectively protect the rotor from collision damage.

B. Can take off safely in a complex environment.

C. Can achieve vertical movement, lateral movement, lateral movement and maneuvering flight in three dimensions.

D. Can achieve a safe landing.

E. Can be controlled by remote control.

Flight Principle and Design Scheme

In the structure, the UAV mainly constituted by a spherical shell with its internal frame structure. Its three views are shown in Figure 1. The spherical shell interior has two central axes, the ring in the middle and similar with the spherical shell can reinforce its structure. The large main rotor in the upper half of the UAV can provide upward lift, the remaining two rotor perpendicular to the main rotor and symmetrical installation on the central axis. UAV batteries and other parts are in the bottom, making lower weight of the UAV is relatively heavy, to ensure the stability of the UAV's longitudinal and making it more safe and easy to take-off and landing.

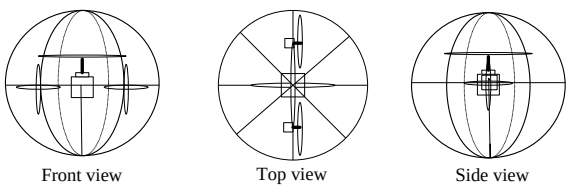

Fig-1: Three views of the spherical UAV

The flight principle of this spherical UAV is: the main rotor driven by the motor can produce a vertical lift, to provide an upward momentum for the UAV, thus

controlling the vertical movements of the spherical UAV. At the same time, the spherical UAV using the two coaxial symmetrical auxiliary rotor which under the main rotor to offset the torque force generated by the main rotor, so that the UAV can balance the force. In addition, the two sub-rotors can control the flight direction of UAV by changing their speed difference. After adjusting direction, the auxiliary rotors can provide thrust to control the UAV flying follow the planning route. Through the coordinated cooperation among the various modules, the spherical UAV can successfully complete the operation of take-off, maneuver flight and safe landing.

DESIGN OF HARDWARE

Hardware Framework

Part of UAV hardware includes control system module, sensor module, wireless communication module, motor control module and power supply module, and use the control system module to share information. The hardware block diagram of the UAV is shown in Figure 2.

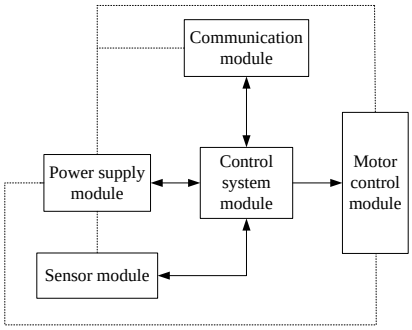

Fig-2: Hardware block diagram of the UAV

A. The control system module is responsible for the coordination of the each module, to ensure that each module can reasonable and orderly complete the control instructions issued by the main controller. Dealing with the feedback information of each module and make the UAV fly normally.

B. The sensor module is used to collect the information of UAV flight speed, attitude and others. The data is processed and sent to the main controller.

C. The wireless communication module is used for wireless communication between ground and UAV.

D. The power supply module is used to supply power to each module at the required voltage.

E. The motor control module is used to drive the rotors in accordance with control requirements.

Choice of Control Chip

When choosing the control chip, on one hand, we must consider to ensure the stability, reliable and safe flight of the aircraft, on the other hand, we should consider the economy, energy consumption, size, performance and so on. Compared with other control chips, ARM chip is a best choice [3]. In this design, we choose S3C2440 control chip based on ARM920 kernel, the control chip can quickly handle the sensor feedback signal, the control algorithm, and quickly respond to the control signals from each module.

Design of Sensor Module

The sensor module is mainly used to collect all kinds of parameters that required for UAV flight. There are three main parameters for the UAV, the angular velocity, acceleration and height, which are realized by ENC-03M sensor, LIS344ALH sensor and MPX4115 barometer. ENC-03M is a single-axis angular velocity sensor developed by the Japanese company Murata, used to measure the angular velocity of the UAV. There is a certain error for this sensor, we can use accelerometer and calculation to reduce it. LIS344ALH sensor is a three-axis accelerometer, it is low cost, low power consumption, and it can stably output of the three rotors flight movement information. While the LIS344ALH framework is very stable, it can be able to withstand a greater impact strength. According to the principle that different height with different pressure, we use a pressure sensor to measure the height, the model is MPS4115. UAV location information is determined through GPS. The chip selected is Jupiter SE880 by the United State SiRF company.

1. Gyroscope module

The gyroscope is mainly used to measure the angular velocity of the aircraft. Figure 3 shows the angular velocity measuring circuit using ENC-03.

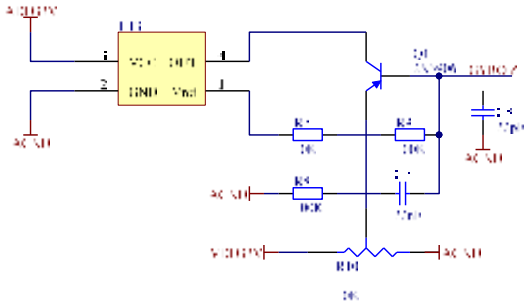

Fig-3: Angular velocity measuring circuit

2. Acceleration measurement module

We use the LIS344ALH accelerometer to measure the acceleration value of the UAV, as shown in figure 4.

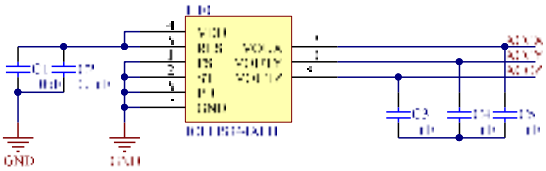

Fig-4: Acceleration measurement circuit

3. Height measurement module

Height measurement module is mainly used to measure the distance between the aircraft and the ground, the UAV we designed use MPX4115 chip. Using the relationship between pressure and altitude, we can measure the height of the UAV [4]. The data measured by the barometer is amplified and transmitted to the main control chip. The height measurement circuit is shown in figure 5.

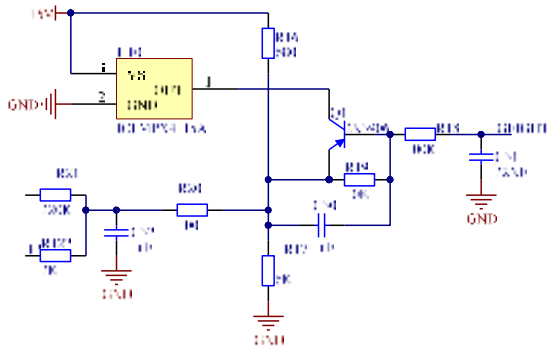

Fig-5: Height measurement circuit

Wireless Communication Module

Wireless communication module is the bridge of ground-air communication, so it is very important in the whole UAV system. In wireless information exchange, it is necessary to maintain the accuracy of information transmission, but also to maintain the stability of the signal. Because the UAV flight distance is not far, so the choice of wireless communication module does not need to be very strict. We choose PCA82C520 chip which working voltage 3.3V and lower power consumption. The configuration and use of PPCA82C520 chip are very convenient. Figure 6 is the circuit diagram of wireless communication module.

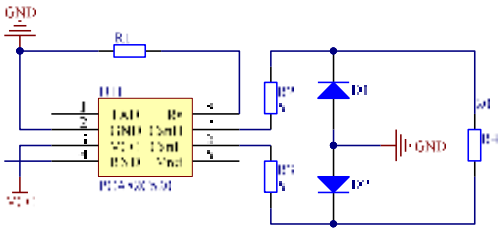

Fig-6: Wireless communication circuit

Power Supply Module

In the UAV work process, each module requires power supply, but different modules require different operating voltage [5]. When the system is running, the ARM operating voltage is 1.8V, the IO port operating voltage 3.3V, the wireless communication module needs 5V, the drive motors and other chips need 11.1V. Therefore, the power supply module needs to supply different operating voltage, including 11.1V, 5V, 3.3V and 1.8V power supply. 11.1V can be directly used 12V battery supply, other power supplies need to be specially designed.

1. Selection of 12V-5V power supply chip

The total required current of the core components of the hardware is about 500mA. The choice of the chip should be higher than the consumption current but not too high, and about 50% of the current remaining capacity should be kept [6]. Therefore, the selection of the chip need not only to meet the requirements of the core components but also meet the requirements of core components current. Based on these problems, we chose 78M05 chip which is small size and the maximum output current is 500mA as 12V to 5V converter chip. Figure 7 is 12V to 5V converter circuit.

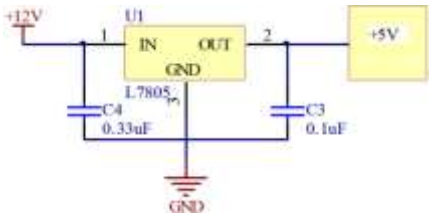

Fig-7: 12V to 5V converter circuit

2. Selection of 5V-3.3V-1.8V power chip

The choice of power supply chip is mainly to consider the order of power supply requirements. The I/O power supply order of the ARM is not required, but the kernel needs strict order requirements. In reality, the power supply sequence and power supply voltage are different from the ideal. The ideal is the core and peripheral power supply at the same time and the power supply voltage is the same [7]. In reality, peripherals will be first power supply, and then is the core, but in normal work requires, the voltage of the peripheral is not higher than the core voltage of 2V. In order to maintain the normal work of the ARM and the core, we should deal with the power supply sequence, and power supply sequence is mainly determined by the power chip, so choose a reasonable chip is particularly important. Based on the above-mentioned problems, the power supply chip selected in this paper is TPS76D318. Figure 8 is the TPS76D318 circuit.

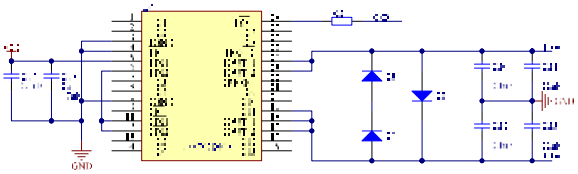

Fig-8: TPS76D318 circuit

In flight process of the UAV, the security issue is very important. In order to improve the anti-jamming of the equipment, we used a number of analog sensors, which also increased the risk of flight. Therefore, in

order to prevent accidents and improve flight safety and reliability, we have designed a power protection circuit to prevent over-current lead to open circuit. Figure 9, 10, 11, 12 is the power supply module protection circuit, 5V voltage regulator circuit, 3.3V voltage regulator circuit and analog voltage regulator circuit respectively.

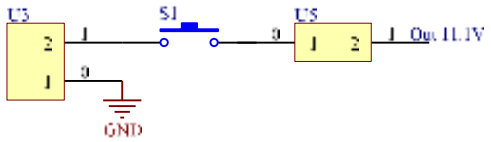

Fig-9: Protection circuit of power supply module

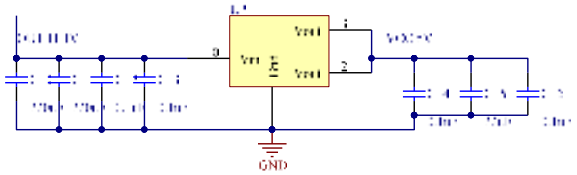

Fig-10: Voltage regulator circuit

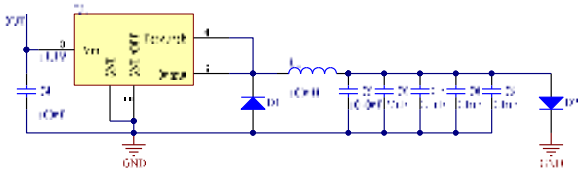

Fig-11: Voltage regulator circuit

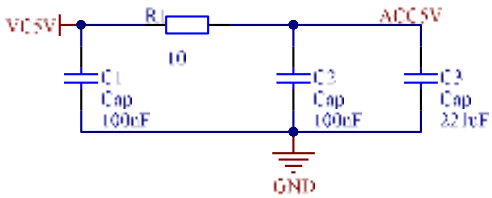

Fig-12: Analog voltage regulator circuit

Motor Control Module

Driving motor is the driving force of the whole system, and is closely related to the aircraft take-off and flight stability. The selection of the motor has two options, one is brush-less motor, the working efficiency of brush-less motor is high and suitable for a variety of working environments with strong ability, but the work process is more complex. Another one is the brush motor, brush motor needs to replace the brush on a regular basis and brush motor is not suitable for dust, muddy, rain and other environments. The brush working process of brush motor will produce heat, but brush-less motor will not. Taking into account the advantages and disadvantages of the two motors, we adopt brush-less motor. At the same time, based on cost-effective, technology, cost and other factors, we choose XXD A2212 model brush-less motor. In this design, we use a TIMx pin of S3C2440 to control the motor speed [8], through a different speed and different rotation direction to control the lift of the aircraft, which can make the aircraft to complete different flight missions in the air.

SOFTWARE DESIGN

Software design of the UAV on the one hand should achieve normal flight, on the other hand should achieve the balance between various modules. The whole control module is divided into main central control module and external control module. The task of the main control module is to complete the system initialization, the system initial inspection, the system self-test, calculate the sensor data, navigation information solution, the implementation of control algorithms, calculation, output control volume and so on. The design of the control software using μC/OS-Ⅱ, μC/OS-Ⅱ is an embedded operating system, most of the code are written in C language. Its function is very powerful, which includes the communication synchronization, task scheduling, interrupt mechanism and time management. Communication synchronization allows each task to be coordinated. Figure 13 is the flow chart of system starting.

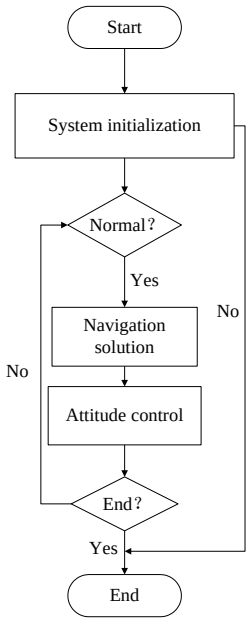

Fig-13: Flow chart of system starting

The entire software system is divided into the main program and the interrupt handler. The main program is the operating procedures for the UAV in normal flight conditions and the work procedures for coordination of various systems. Interrupt handling routine mainly deals with the signal transmission and communication between peripherals and ARM. When the system power on, the system will self-test, if self-test is normal, we can choose to fly automatically,

otherwise it is manual flight. Different flight modes will have different control methods.

The overall design of the UAV main program is shown in Figures 14, and figure 15 is the interrupt handler.

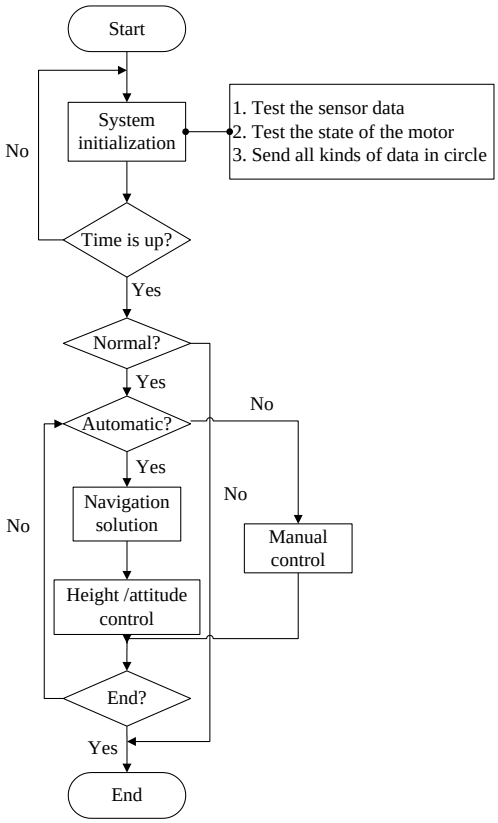

Fig-14: Overall design of the UAV software system

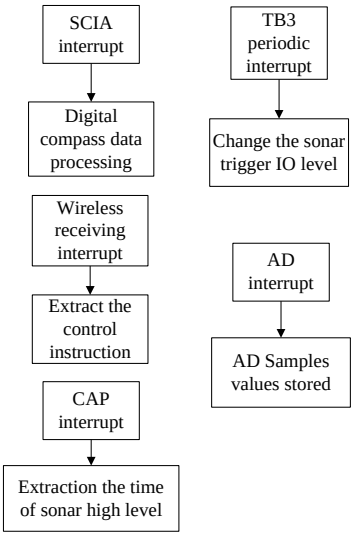

Fig-15: Interrupt handling routines

CONCLUSION

In this paper, we design an unmanned aerial vehicle based on ARM processor. Unlike other UAVs, the UVA designed in this paper has a three-rotor configuration, and is covered with a protective shell. This makes the UAV have better drop-resistance performance. In this paper, the software and hardware design of the UAV is introduced in details, including the selection and function of each module. The working procedure of the UAV is designed, and the hardware and software design can make the UAV realize autonomous flight. Also, it can better meet the requirements of remote manual flight.

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