

## Automatic control experiment box on electronic education

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**Abstract.** This paper discusses an automatic control experiment box applied to engineering education and competition trainings. Based on the analysis about common functions of robots, this paper generalizes four modules: control circuit module, mechanical action module, acoustooptic display module and information interaction module. This comprehensive experiment box is a hardware and software combined platform that can be implemented to different kinds of electronic education, for example, curricular innovation activities, students' innovation and entrepreneurship training program, undergraduate electronic design contest, embedded contest and so on.

### Introduction

Among various fields of modern science and technology, automatic control becomes increasingly important. Without the direct involvement from man, machines can operate automatically according to the predetermined rules.

In the paper, a brief introduction about the relevant literature on automation control and the education experiment box are provided, and then the functions and constitution, including major elements of control board that is the center of the box are discussed, and followed a series of basic function modules and a discussion of the range and role of the experiment box's application on education.

### Functions and constitution of control board

In different kinds of extracurricular activities and contests, Renesas, Texas instrument and ARM control chips are widely used. To meet the requirements of application, mainstream control chips should be thoroughly studied and the outcome of previous contests, especially the control algorithm and code, should be combined as well. The experiment box is divided into three parts: system control module, basic function module and applied teaching module. This design focuses mainly on the control module that is the center of the experiment box and utilizes the chip STEM32F407 and the chip G13 from Renesas.

With STEM32F407 and G13, control board provides power supply interface, driver program downloading interface, scalable interface and some necessary peripherals.

STM32F407 is based on the high-performance ARM® Cortex™-M4 32-bit RISC core operating at a frequency of up to 168 MHz. The STM32F407 incorporates high-speed embedded memories, up to 4Kbytes of backup SRAM, and an extensive range of enhanced I/Os and peripherals.

Some standard and advanced communication interfaces are added according to the experiment box's needs and functions. They are respectively, IIC, UART, SPI, USB and so on. USB has a wide range of application with the advantage of small voltage and convenience. IIC is a special kind of synchronous communication with the advantage of less interface cables, high rate and simple control form. SPI is full-duplex and synchronous communication bus with high-speed. It has the advantage of occupying only four pins, saving more space for PCB. Therefore, this communication protocols is generally applied. UART, as a part of a computer and being generally integrated on the link of other communication interfaces, is an asynchronous receiver transmitter.

Meanwhile, there are also some predominant peripherals. Keyboard is the most widely used data input device in SCM application system. The keyboard, which is the aggregation of buttons, is a normally-open switch. Two contacts are often in disconnected state and they are closed when they are pressed. The independent keyboard interface's each button occupies one I/O line. Although it is simple to make programs, the utilization efficiency of I/O lines is very low. However, the matrix keyboard interface improves the utilization, which would be implemented when there is a large number of buttons.

μC /GUI is another important part of control board. It provides any application that uses display of LCD with high-efficient and independent graphic user interfaces, being adapt to single-tasking or multi-tasking systems.

### Infrastructure function module

The existing infrastructure function modules are inserted into control board directly. This paper designs corresponding programs and GUI interfaces in accordance with each module. The main modules involve motor speed-testing, gyro, temperature testing and distance testing. The whole thinking is thoroughly shown in figure1.

The introduction of each module is shown as below:

The fundamental distance-testing device is the accelerometer that is widely used to measure the acceleration of a moving vehicle. It is composed of inspection quality, support, potentiometer, spring, damper and the housing. From acceleration, other useful index of vehicles can be gotten, like dynamic load or real time location of aircrafts and rockets.

Gyroscope referred as an indispensable and sensitive element of the automation control system is considered as a signal sensor. In one side, it will supply accurate location, velocity and acceleration, making it convenient for drivers to control aircrafts. On the other side, making use of the signals can complete the controlling of flight attitudes and orbits.

In wireless communication module, this paper discusses the chip NRF24L01. It uses the FSK modulation and Enhanced Short Burst communication protocol, realizing one to one or one to six wireless communication whose velocity is up to 2Mbps. Users can use the function easily by reserving five GPIOs and interrupt input pin for the system, especially for MCU system.

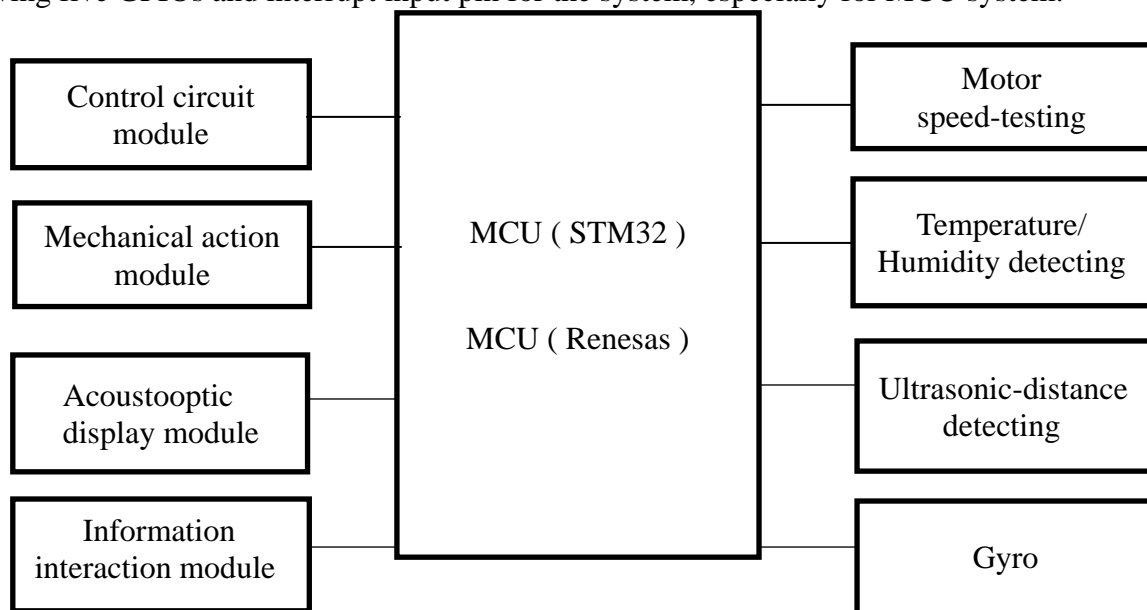


Figure1.

DALLAS company produces DS18B20 that is a temperature sensor with one-wire bus interface. Compared with traditional thermistors, it is a digital temperature sensor with small volume, being more easily applied to wide voltage and simple microprocessor interface. The frame of one-wire bus which is concise and economic largely enhances the anti-interference of system and realizes the 9 to 12 bits of digital readout mode.

Ultrasonic ranging module is equipped with the function of non-contact sensing from 2cm to 400cm and the ranging accuracy is up to 3mm. Ultrasonic transmitter, receiver and control circuit are all included. This ranging module adopts TRIGGER with I/O interface to measure distance and then automatically sends 8 square waves with 40KHz, detecting whether there is signals to return. When the signals come back, ECHO will output a high-level. The formula will be gotten:

$$\text{The testing distance} = \frac{(\text{the duration time of high-level}) * (\text{sound velocity})}{2}$$

### Application of electronic education

Engineering education is the activity of teaching knowledge and innovations related to the professional practice about electronic engineering. Through the practice in laboratories, students' practical abilities would be strengthened and the spirit of creation would be inspired as well. More and more students will take part in understanding the knowledge of embedded systems. Therefore, this multifunctional experiment box is instrumental in guiding students to tap more possibilities in automation controlling.

These infrastructure function modules shown as above can constitute applied teaching modules directly, for example, four-axis aircraft, wheeled robots, crawler robots, under-water robots, supporting various extracurricular activities, academic competitions, open experimental projects, software and hardware combined graduation designs and accelerating the pace of teaching reformation about SCM and embedded systems. After being trained by each module in this hardware platform, users can make some improvements based on the suit or get on teaching demonstration.

#### Aerocraft

Aerocraft is a good case in this point. Nowadays, they are the cutting edge of scientific and industrial fields, combining the advantages of small volume, high mobility, stable performance, low energy consumption, simple mechanical components and various flying attitude.

Quad-rotor aircraft is mainly composed of control board, gyroscope, motor and ultrasonic ranging module. Firstly, a hardware platform composed of body, wireless communication module, attitude sensor and flight control module should be set up. Secondly, through programs, upper computer is linked with the flight wirelessly. Next, flight controllers will collect information and do deal with the attitudes data from which flight's real time location and accurate attitudes are gotten with the posture solver algorithm. Lastly, aerodynamic modeling and PID attitude control algorithm are completed. Besides that, motor is in charge of controlling brushless DC motor, and OV7620 camera adds the function of self-tracing and aerial photography. The picture of the actual object is shown in figure 2.



Figure2.

Therefore, this new designed quad-rotor aircraft has a very excellent prospect both in civilian and military fields.

## Manipulator

By combining these modules discussed above, this paper also creates a bionic manipulators which is divided into two parts: remote-controlling terminal and controlled terminal. Remote-controlling terminal measures the posture of human arm and finger bending through the gesture recognition bracelet and sends the data about gestures to the controlled terminal through wireless communication module. Then the controlled terminal will map the calculated data to the rotation angle of each joint of manipulators, which would control the motion of motors. The manipulator can implement the remote controlling from human body and realizing the imitation and learning of the human-arms' movement, cooperating with the human-computer interaction and memory storage.

With the experiment box, many achievements, like first prize or second prize of national college student electronic design competition and first or second prize of electronic design competition for college students in Jiangsu Province, have been gotten. Some certificates of awards about the achievements are shown in figure 3.



Figure 3

## Summary

This experiment box combines basic modules, having provided comprehensive functions for students to get a closer look of knowledge about automatic control and embedded system and revolutionized the electronic education. Based on the experiment box, it enlarges students' view of electronic engineering and more automatic control works will be created, which would bring more convenience for people in common lives.

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