Two Axis Micromouse Servo Controller Based on ARM9

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Abstract: The micromouse is an intelligent robot that is designed to search a shortest path to the destination in an unknown maze, which can memory the complex maze information automatically after searching. Micromouse based on MCS-51 series MCU are affected by the hardware and software, is difficult to use more advanced intelligent algorithms, which leads to the micromouse can not be quickly explore the maze and reach the set destination. Hardware and software of micromouse based on ARM9 are discussed, also with the experimental results. Copyright © 2014 IFSA Publishing, S. L.

Keywords: Micromouse, Embedded technology, Maze, Genetic algorithm.

1. Introduction

Micromouse championship is an international robotics competition is an event where small robot micromouse solves a 16 × 16 maze. It began in late 1970s, although there is some indication of events in 1950 [1-3].

The maze is made up of 256 squares arranged in a 16 by 16 grid of cells, each 180 mm square with walls 50 mm high and 12 mm thick, the length of the wall is 168 mm. The micromouse is completely autonomous robots that must find their way from a predetermined starting position to the central area of the maze unaided. The micromouse will need to keep track of where it is, discover walls as it explores, map out the maze and detect when it has reached the goal. Having reached the goal, the micromouse will typically perform additional searches of the maze until it has found an optimal route from the start to the center. Once the optimal route has been found, the micromouse will run that route in the shortest possible time.

Now the events are held worldwide, and are most popular in the UK, US, Japan, Singapore, India and South Korea.

Micromouse is an electro-machine device which consists of 3 main subsystems; they are the driver system, an array of sensors and control system.

The sensors will tell the CPU the current state of the surrounding where the wall and paths are, then the CPU sends signal to drive circuit to control the moving of the micromouse.

The control system runs the maze-solving algorithm on the information received by the CPU through the sensors. The mouse will explore through the maze and store the mapping of the maze inside its
memory. After that it will calculate the shortest possible path and try to run as fastest possible timings.

S3C2440A is designed to provide hand-held devices and general applications with low-power, and high-performance micro-controller solution in small size. The S3C2440A is developed with ARM920T core, 0.13 μm CMOS standard cells and a memory compiler. The S3C2440A offers outstanding features with its CPU core, a 16/32-bit ARM920T RISC processor designed by advanced RISC machines, Ltd. Its low-power, simple, elegant and fully static design is particularly suitable for cost- and power-sensitive applications, especially to micromouse design.

2. Two Axis Micromouse Based on ARM9

Reference to some foreign advanced design concepts and experience of 2013 the UK international micromouse competition, a new micromouse based on ARM9 (S3C2440A) is designed as shown in Fig. 1. The two axis micromouse intelligent servo management system including: command input, motor drive, infrared sensor acquisition and judgment, power protection, information display.

3. Hardware Design of Two Axis Micromouse Based on ARM9

3.1. Command Input

To achieve the function of searching, system reset, acceleration searching, acceleration dashing, micromouse needs 4 independent switches connected to ARM9. By different switch combinations you can get different speeds. To reduce interference, switch button input signal is shaped by 74VC14 then input to S3C2440A, switch circuits on the same principle, system reset switch circuit as shown in Fig. 2.

3.2. Power Supply

The micromouse needs a self-reliant and independent power source. Therefore, it runs on the battery power. There are a few things to consider when design the power supply for the micromouse. First, you need to know what kind of motor will be used. Second, how much power does the motor needs for the best performance.

For the micromouse, DC motor will be used. This motor requires 6 V and 0.7 A. Since the speed and torque performance of the motor are based on the flow of current from the driver to the motor winding, the lower the inductance, the faster the current gets to
the winding and the better the performance of the motor. Therefore, 2 times greater than the supply voltage of the motor is used for the micromouse and 3 of 3.7 V Li-ion batteries are used which will output the highest voltage is 12.6 V, the average voltage is 11.1 V. Also, LM2937IMP-2.5 step-down voltage regulator is used to regulate output voltage to 3.3 V. LM2937IMP-2.5 is monolithic integrated circuit that provides all the active functions for a step-down switching regulator, capable of driving a 1 A load with excellent line and load regulation. It offers a high-efficient replacement for popular three terminal linear regulators. The following circuit is used to regulate output voltage to +3.3 V.

![Power supply circuit](image)

**Fig. 3. Power supply circuit.**

### 3.3. DC Motor

DC motor works from a direct current supply. Voltage is applied to the motor terminals and the motor begins to rotate. Torque is developed in a DC motor by the armature (current-carrying conductor) being present in the motor field (magnetic field) [4]. Torque in a DC motor is to provide the mechanical output to drive the piece of equipment that the DC motor is attached to. As the armature picks up speed, CEMF is developed in a DC motor by the armature (conductor) rotating (relative motion) in the field of the motor (magnetic field) that tries to oppose the current flowing in them. DC motor (T006SR+IE2-512) is used in the system. Its parameters as shown in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>6 V</td>
</tr>
<tr>
<td>Power</td>
<td>4 W</td>
</tr>
<tr>
<td>Efficiency</td>
<td>85 %</td>
</tr>
<tr>
<td>Speed</td>
<td>7500 rpm</td>
</tr>
<tr>
<td>Torque</td>
<td>10 mN/m</td>
</tr>
<tr>
<td>Weight</td>
<td>35 g</td>
</tr>
<tr>
<td>Diameter</td>
<td>22 ±0.5 mm</td>
</tr>
<tr>
<td>Length</td>
<td>24±0.5 mm</td>
</tr>
<tr>
<td>Shaft diameter</td>
<td>2 ±0.1 mm</td>
</tr>
<tr>
<td>Encoder</td>
<td>512 lines</td>
</tr>
</tbody>
</table>

### 3.4. Motor Drive Circuit

The L298 is an integrated monolithic circuit in a 15-lead Multiwatt or PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage. The L298N can drive two DC motor. Motor drive circuit based on L298N as shown in Fig. 4.

### 3.5. Infrared Sensor Circuit

Sensors are the most critical of all the systems. The sensor is the only way for the micromouse to communicate with its surroundings. It reads whether there is a wall or not and based on the information collected by the sensor [5]. The accuracy of the micromouse relies on the quality of sensors.

There are 6 infrared light sensors to detect walls and position when the micromouse is in the maze. One pair of the sensors is used to detect the front wall and position when stopping. There is one pair of the sensors facing at 45 degree angle left and right each. And the last one pair of the sensors is used to detect the left/right wall at 90 degree angle. Both 45 and 90 angle sensors are used to position the micromouse while moving.

The infrared LED emits the infrared light. If there is a wall, the infrared detector will receive the reflected light from the wall. The intensity of the reflected light will depend on how far the wall is located from the micromouse. Therefore, by knowing the level of the intensity, we can adjust the distance to detect the walls. Infrared sensor transmitting and receiving circuit as shown in Fig. 5.
In the circuit, SFH4550 emits the infrared light, change the value of R16 can change the intensity of the reflected light, TSL262 accepts the reflected infrared light and convert it, then input the value to ARM9.

3.6. Current Protection

In the servo system, Li-ion battery supply energy to drive the motors, high level power will be needed when micromouse in fast searching and dashing. Without protection, the current of battery will be very high especially when its voltage is in very low stage. High level current will harm the battery. In order to protect battery, current detection and protection circuit is designed.

The protection circuit principle as shown in Fig. 6: the current from sensors go through a resistor can get a voltage, then the voltage is input to ARM9(S3C2440A).
4. Software Design of Two Axis Micromouse Based on ARM9

The software will be an important part to determine the performance and accuracy for this project. Fig. 7 shows the flow chart of software.

```
Begin
  System initialization
  state of battery
    NO
      searching
      Destination? NO
      Back to start
    NO
      Maze optimization
      dashing
      return
  Battery handling
Fig. 7. Flow chart of smart servo system software.
```

The speed of searching and dashing determines the time which micromouse takes, but also determines the entire competition results. Because the micromouse uses rare earth permanent magnet DC motor, the motor speed is proportional to the voltage across the motor. Motor’s voltage is proportional to the duty cycle of PWM control waveform, so that the motor speed is proportional to the duty cycle of PWM. TCNTBn determines the S3C2440A system’s PWM frequency, PWM pulse width determined by the TCMPBn, the duty cycle is TCMPBn / TCNTBn. Set the PWM flow chart as shown in Fig. 8.

```
Setting register GPBCON, ARMD (S3C440A) port
Setting register TCFG0 Dead zone length, prescale values
Setting register TCFG1
Setting register TCNTB1 Setting register TCMPB1
Setting register TCON Update Timer 1
Enable dead zone, start timer 1, automatic loading
Fig. 8. Flow chart of PWM.
```

Genetic algorithm is an adaptive searching technique based on a selection and reproduction mechanism found in the natural evolution process, and it was pioneered by Holland in the 1970s. It has become very famous with its global searching, parallel computing, better robustness, and not needing differential information during evolution [6-10]. To reduce the time of maze optimization, using genetic algorithm to generate optimal maze, the process as shown in Fig. 9.

```
Maze information
  Coding
    Generate the initial population
    Population individual fitness assessment
      Termination condition is satisfied
        yes
          choose operation crossover operation variation operation
          Optimal Maze
            encode
              Output Optimal path
              no
Fig. 9. Flow chart of maze optimization Based on GA.
```

5. Experiment

The experimental design of micromouse as shown in Fig. 10.

```
Fig. 10. Prototype of micromouse.
```
After complete searching in the maze, using genetic algorithms gets two optimal paths as shown in Fig. 11.

![Maze and its path](image1.png)

**Fig. 11.** Maze and its path.

In simulation test, set PWM frequency 1000 Hz, the motor can be smoothly rotated. With a digital oscilloscope, PWM waveform at duty cycle of 30% as shown in Fig. 12(a), duty cycle of 50% as shown in Fig. 12(b). As the duty cycle changes, the motor speed is changed.

![Waveform of PWM](image2.png)

(a) D=30%

(b) D=50%

**Fig. 12.** Waveform of PWM.

PWM waveform from drive circuit to DC motor X and motor Y as shown in Fig. 13, it can be seen from the figure, duty cycle of the PWM to two DC motor is almost equal, thus ensuring two differential speed drive DC motors can run with the same speed, which ensure the accuracy of the straight line navigation.

![Waveform of PWM to motor](image3.png)

**Fig. 13.** Waveform of PWM to motor.

In straight line navigation, torque waveform of DC X and Y as shown in Fig. 13, it can be seen from the figure, two motor’s torque have the same value, with a very small ripple, thus ensuring two DC motors can run with the same acceleration, which ensure the accuracy of the straight line navigation.

![Waveform of motor torque](image4.png)

**Fig. 14.** Waveform of motor torque.

6. Conclusions

The two axis micromouse project is based on ARM9, can be easily achieved its position, speed, as well as acceleration control. The full use of existing powerful integrated chip-ARM embedded system in C language programming, eliminates many hardware circuits so that the control system has been greatly simplified. Experiment results show that using PWM strategy can easily achieve the two axis DC motor servo control.
References


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