Experimental Research and Analysis on Smart Car with Electromagnetic Runway

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***Abstract*—In this paper, a smart car which is able to independently identify wire line is made. With a car model, a dc motor and chargeable batteries, it is based on the multi-function MCU. The smart car is guided by the electromagnetic field and along a certain path. The whole system is a closed-loop control system through the electromagnetic sensor collection of road information and PID control algorithm on the starting line, straight, curves, etc.**

Keywords- multi-function MCU; smart car; electromagnetic field; PID control.

I. INTRODUCTION

The smart car is a collection of high technology. Under the network environment it has the automatic recognition, automatic driving, automatic speed limits and other advanced features [1]. With automatic control, computer technology and information technology developing, the intelligence tool in the industrial production and daily life plays an important role [2].

As an important part in Intelligent Vehicle—Highway Systems， smart cars in countries around the world along with the computer technology, network technology and communication technology are also rapidly developed and deepened [3].

Traditional design method of smart car is based on photoelectric signal acquisition, CCD image processing, but the demand is higher on the surrounding environment. Smart cars are susceptible to be interfered [4]. However, the electromagnetic signal sensing, as this paper says, overcomes the weakness of sensitivity of light, temperature, humidity and other factors.

II. ELECTROMAGNETIC SIGNAL DETECTION PRINCIPLE AND THE OVERALL SYSTEM DESIGN

Smart cars run according to the center line by the wires of 100 mA alternating current electromagnetic field generated by the test path. Smart cars use the navigation path of alternating current frequency to 20 kHz, which belongs to the very low frequency electromagnetic wave. Wires is surrounded by electric field and magnetic field, smart cars realize the electromagnetic navigation purposes by detecting the corresponding electromagnetic field strength and directions [5].

The sensor module and steering gear module is responsible for the path detection; The power management module is responsible for the power supply of the whole system；The motor module is responsible for the driver； MCU control module is responsible for data processing and control strategy of the implementation of the track. In addition, we still can increase the photoelectric encoder and other auxiliary modules used to detect speed, decision-making to provide the reference for speed. Main peripheral circuit modules of the smart car are shown in Fig. 1.

The direction of the intelligent car control is realized through controlling the steering gear by PWM wave. Steering gear is controlled through the cycle of fixed pulse signal control, the steering gear indexing is proportional to the pulse width, and the continuous pulse signal can be realized by the PWM. Steering gear inside will generate a reference signal frequency which is 50 Hz. In order to determine the size of the steering and corner reference signal, the given PWM wave is compared with external pulse duration. Motor adopts the classical PID control. PID, with its simple structure, good stability, reliable operation, is easy to adjust and become one of the main technology of industrial control [6]. Motor control system block diagram is shown in Fig. 2.

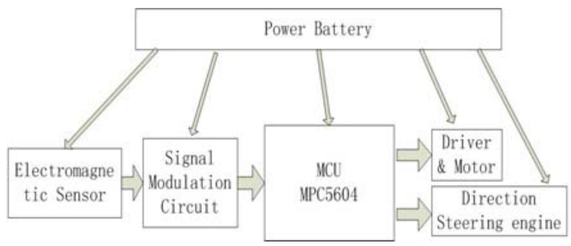

Figure 1. The main system module.

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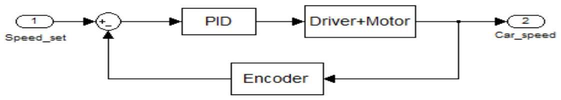

Figure 2. Motor control.

III. SENSOR DESIGN AND EXPERIMENTS

The magnetic field around the wire is a vector field. Two vertical components of magnetic field vector can be induced, and we can get the magnetic field intensity and direction. When the current in the conductor changes according to certain rule, the magnetic field around the wire will change too. So certain electromotive force will be induced around the coil. According to Faraday's law, the relationship of internal induced voltage E coil magnetic field sensor with magnetic field B(t), the electromagnetic coil circle number N, and cross-sectional area of is [7]:

$$E = (NA)\times(\mu_0\mu_r)\frac{dB(t)}{dt} = -\frac{d\phi(t)}{dt} \tag{1}$$

Due to the design of the current in the conductor (20 kHz) is with low frequency, the coil in the induction electromotive force could be approximate to:

$$E = -\frac{d\phi(t)}{dt} = \frac{KdI}{\tilde{r}\,dt} = \frac{K}{\tilde{r}} \tag{2}$$

According to Faraday's law, we use induction coil to induce voltage, and then use MCU to process information after AD transformation, and make a feedback. Finding the right inductor, therefore, is the primal task of the design of electromagnetic sensors.

After a large amount of inductance tests, we found only in 10 mH inductance, electromotive force curve can be induced as relatively neat sine wave which is shown in Fig. 3. Its frequency and track the power frequency is consistent (20 kHz), and the amplitude is bigger than other models. The amplitude changes with the distance between conductors-the distance is nearer, the conductor is larger.

According to the tests, 10 mH inductors are determined to be used as testing sensor of the wire, but its induction signal is weak, and mixed with clutter, so the signal processing must be carried on. The designed sensor is as shown in Fig. 4.

To get ideal signal, the following three steps should be taken: The signal filtering, the signal amplification, and the signal detection.

A. The signal filtering

To realize frequency selective circuit, we use LC circuit in parallel, the resonance frequency of the circuit is：

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{3}$$

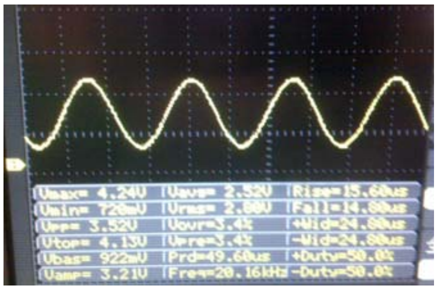

Figure 3. Signal waveform the sensor collected.

The frequency of the induced electromotive force (f=20 kHz) is known. Inductance of the induction coil is L=10 mH, and we can calculate that the capacity of the resonant capacitor is 6.33 nF. Usually we can buy capacitance of nominal capacity of 6.8 nF in the market, so we choose 6.8 nF capacitance as a resonant capacitance.

B. The signal amplification

Handled by the first step, the voltage waveform of 20 kHz is neat, but the amplitude is small, so it should be amplified, so we choose a total of transistor amplifier circuit. In general, the static working point should be set to the middle position which is 2.5 V, and in this way the ac signal distortion can be prevented.

C. The signal detection

We use two diodes to do the voltage-multiplying detection, voltage-multiplying detection circuit can get dc voltage signal which is proportional to peak-peak. Because this kind of diode open general at around 0.1~0.3 V voltage, which is less than ordinary silicon diodes (0.7 V), so we can use diodes to increase the output signal dynamic range and increase the sensitivity of the overall circuit. 1N4001 is chosen.

Through the experiment we find when the sensor is away from electricity enameled wire. After LC series resonant circuit, the peak-peak of sine wave(20 kHz) is approximately 54 mV, the waveform is shown in Fig. 5. When the sensors near the enameled wire, the waveform as shown in Fig. 6, the peak-peak is at about 452 mV. It can be seen that with the change of the displaced position the output amplitude of the signal can make a big change.

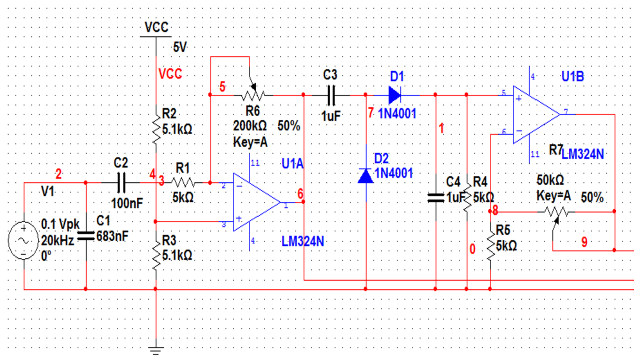

Figure 4. The circuit of the sensor

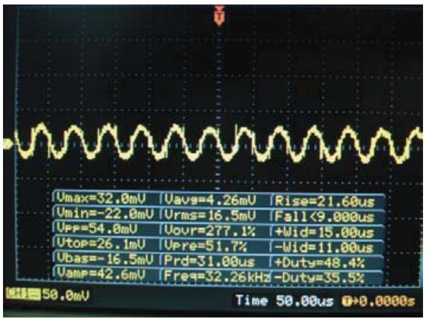

Figure 5. The waveform away.

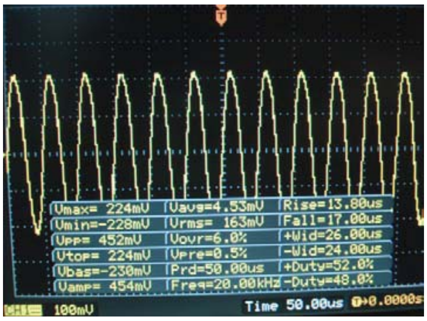

Figure 6. The waveform near.

At the same distance, after the late amplification, detection, and filter, the output dc filtering signal average value is about 279 mV away from the wire. When near wire, the average value is about 4.32 V.

IV. Overall System Circuit Design and Software Algorithm

The system uses a standard MPC5604 MCU clock circuit [8].

The smart car system software is written based on single chip microcomputer, which is mainly used in the PWM module, TIM module, I/O module and SCI modules such as modular design. The PWM module is mainly used to control the steering gear and motor function; TIM module is mainly used in the speed measuring module and data acquisition, capture interrupt and calculating the instantaneous velocity; I/O module is mainly used for assigned to switch and laser scanning, information acquisition; SCI module is mainly used in the wireless serial debugging module. Body flow chart is shown in Fig. 7.

The main program module only process initialization and only speed gear selection. In order to make the car control more orderly and timely, we use the timer interrupt as precise timing in 64 ms, that is an adjustment direction and speed every 64 ms. The input capture interrupt detect speed, and feedback to the controller to adjust speed. The interrupt and other programs are simultaneous and will not affect the sequence of other parts.

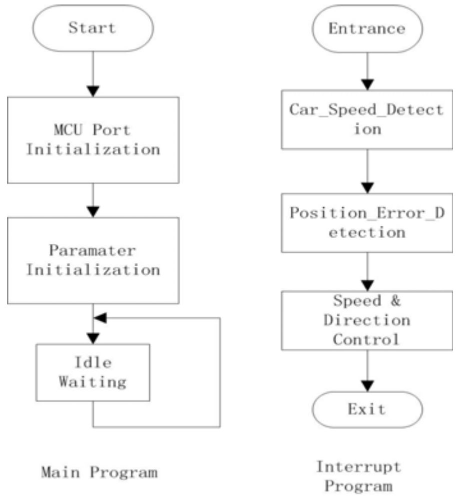

Figure 7. The flow chart of main program and of input interrupt program.

PWM module of the microcontroller is used in the program. We set up two lines of PWM wave to control the steering of gear, and the steering angle and the relationship between PWM duty cycles are obtained from the experiment. The feedback value is known with the difference in value by the counter input of the capture interrupt. By the time every pulse is measured by speed motor, the program will enter a disruption and remember it. In this way the speed of the machine can be got by reading two counter differences.

Motor control with classical PID algorithm is shown in Fig. 8.

Through the above principle, we conclude Kp, Ki and Kd values by trial and error method. Among them, Kp=220， Ki=50， Kd=50， and the motor PID output value is tested, the response curve is shown in Fig. 9.

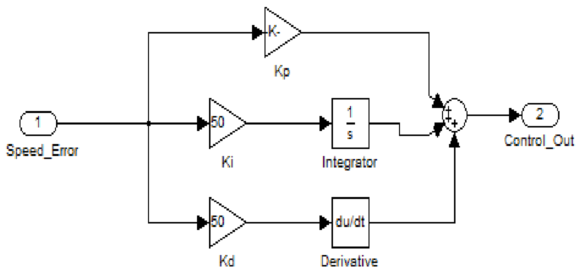

Figure 8. PID control block diagram.

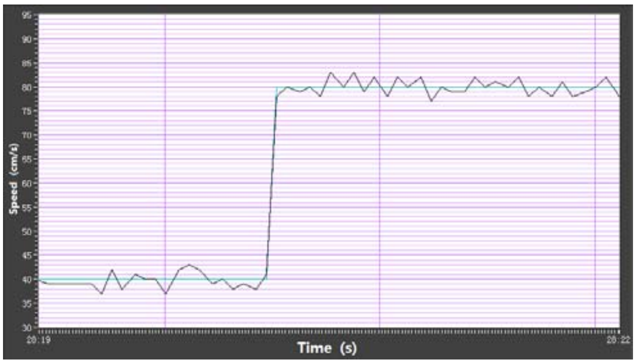

Figure 9. PID controller output.

From the chart we can see its adjustment time is short, with some ripples after stable. But this tiny influence can be ignored. Through an external force to the rear wheel, that is, a disturbance, we found out that he can quickly restore stability.

V. CONCLUSION

The design of smart cars is a complicated process. This design is done on the basis of the original design. In the design of the control system of smart car, conclusions can be drawn as follows:

1) A large number of experiments are done for the design of electromagnetic sensor and ultimately a sensor is determined for the requirements of the runway.

2) Based on the single chip processor, other peripheral circuits are designed, and so is the correspond interface to connect with the single-chip microcomputer in order to make MCU control all parts of the smart car.

3) On the basis of experiments, the steering angle, motor speed and the relationship between the PWM are tested to finally finish the motor PID algorithm.

4) This design deepens the technology of smart cars and enriches the methods to identify the intelligent car. Successful experiments and simulations draw a conclusion which is helpful. Moreover, it is the very basic work of the development of intelligent vehicle.

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