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Design and Development of Vehicle Reversing Brake Assist System

Wei Guo[1], Yuheng Qiao[2]

[1]DongYan Science & Technology Development CO., LTD, Wuhan, China
[2]Institute of Electrical and Power Engineering, Taiyuan University of Technology, Taiyuan, China
Email: dfgwei87@163.com

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Abstract

Through the analysis of the current vehicle reversing braking system, the paper introduces the safety hazard of the vehicle in the reversing state and the factors that affect reversing braking effect and the weakness of control system. Aiming at the existing problems, designing and development of vehicle reverse brake assist system. This method that uses the STC12C5A60S2 single-chip receives GPS vehicle speed signal, and reversing radar distance signal to determine the safety status of the vehicle reversing can realize the accelerator pedal and brake control, and improve the safety of vehicle reversing. To avoid the driver accidentally stamped the accelerator or delayed braking caused vehicle accident is of great significance to the optimization of vehicle braking system.

Subject Areas

Industrial Engineering

Keywords

Braking System, Single-Chip, Accelerator, Handbrake Motor, Safety

1. Introduction

With the rapid increase of car ownership and the continuous improvement of vehicle speed, the safety of automobile has been widely concerned, especially the active safety has become the focus of scientific research. According to statistics, from 2011 to 2014, the number of deaths from vehicle accidents rose from 29,618 to 34,292, with an increase rate of 15.8%; the number of the private car ownerships increased from 58 million 140 thousand to 105 million 590 thousand, with an increase rate of 81.6%; the number of the drivers who have

one-year experience increased from 26 million 140 thousand to 29 million 670 thousand, with a growth rate of 13.5%. People often use the brake system when they use cars, but the handbrake system is often ignored by people. So, more traffic accidents that by wrongly using handbrake or the handbrake system breakdown are often seen [1]. In traffic accidents, reversing accidents account for a large proportion, for example: 2011 Yangzi Evening News reported that from January 2011 to August, more than 20s traffic accidents caused by handed brake system. This is half of accidents that traffic police six brigades counted in one day, the traffic management department of Nanjing statistics the traffic accidents in from April 1 to 19, 2015. It shows 564 accidents within 20 days about reversing, nearly 30 accidents everyday on average.

Under such a severe situation, more and more people realize the importance of using advanced technology to assist the driver to monitor and alarm the environment of people, vehicles, roads and other environments which affect the highway traffic safety. In the critical case, the system actively interferes with the driver's control, assists the driver to deal with the emergency, and prevents the car crash accident. Thus, the vehicle safety system will develop towards intelligent and active technology [2].

With the development of electronic technology, microwave radar ranging, laser ranging and ultrasonic distance measurement have appeared. The first two methods are generally used for military and industry because of their difficulty in technology and high cost, while ultrasonic ranging is relatively difficult because of its low technical difficulty and low cost, which is suitable for civilian promotion [3]. Ultrasonic wave, as a special sound wave, also has the basic physical properties of acoustic transmission—reflection, refraction, interference, diffraction, and scattering [4]. Ultrasonic distance measurement is to use its reflection characteristics. About ultrasonic ranging, it has been studied in foreign countries [5] [6]. Through the development of Technology, ultrasonic technology has been mature in China.

This paper focuses on analysis of factors that affecting automobile braking when it is reversing and design and development vehicle reversing brake assist system. This method that uses the STC12C5A60S2 single-chip receives GPS vehicle speed signal, and reversing radar distance signal to determine the safety status of the vehicle reversing can realize the accelerator pedal and brake control, and improve the safety of vehicle reversing. It can prevent vehicle accidents caused by drivers mistakenly stepping on the accelerator when reversing. It is an important guiding significance for the optimization of vehicle braking system.

2. Vehicle Safety Analysis in Reversing Condition

Most cars are equipped with reversing radar or backing images right now, however, from the above statistics, there is still a higher risk of accidents when reversing the car. With electronic handbrake passenger car as the research object of this paper, this paper analyzes the safety of vehicle reversing condition.

2.1. The Principle of Electronic Handed Brake

At present, electronic handed brake can be divided into three forms: mechanical handed brake, electronic control zipper type handed brake, electronic brake caliper. With the continuous improvement of the safety performance of passenger cars, the use of drum brakes gradually reduced, the mechanical handed brake also gradually knocked out. Electronic control zipper type handed brake easily changes become by the original mechanical structure, but with the use of time, the line of handed brake will gradually lose their elasticity, loss of function. So it takes the electronic brake caliper system.

The electronic brake caliper usually has electric brake control unit, reversing light switch, inclination sensor, clutch pedal position sensor, motor and brake lights. Hall clutch position sensor for detecting the clutch pedal position signal, generates a pulse width modulated signal is transmitted to the brake control unit, the vehicles in the process, the function of electronic parking brake safety starting. The two rear wheels of car have both a brake executive motor, which is used to compress the brake shoe through the motor on the brake housing and realize the parking brake of the two rear wheels. The braking motor is mainly composed of a DC motor, a brake piston, a toothed belt, a swash plate, and a drive mandrel, as shown in **Figure 1** and **Figure 2**. The rubber bearing is connected between the motor and the driving mechanism, while the toothed belt is a helical belt to reduce the running noise [7].

When starting the parking brake, the driver operated electronic parking brake system button, ECU will control the motor worked and the piston of brake caliper to move, generating mechanical clamping force and brake. The internal structure of the motor is shown in **Figure 3**, and the motor drive voltage is 12 V.

The traditional mechanical parking brake system uses the driver to manipulate the brake handle of the car, drives the brake shoe to open or the brake caliper piston moves to complete the parking and the braking force is entirely from the driver [8]. The power of the electronic parking brake system is derived from the motor, it can stay maintained brake automatically and automatically start and release. Automatic parking brake function can assists the driver to control

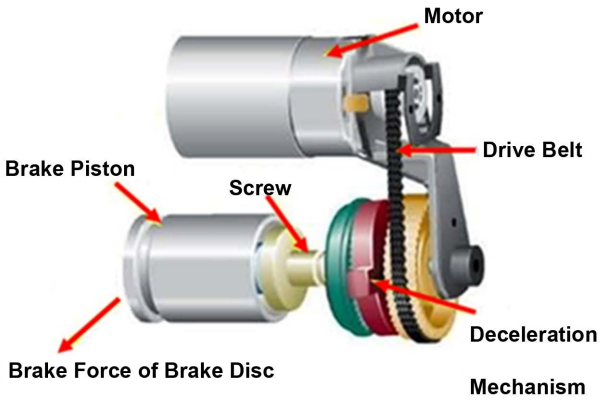

Figure 1. Electronic handbrake executive motor structure.

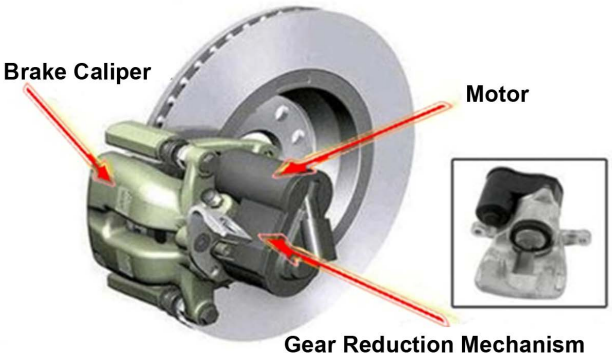

Figure 2. Overall structure of electronic parking brake caliper.

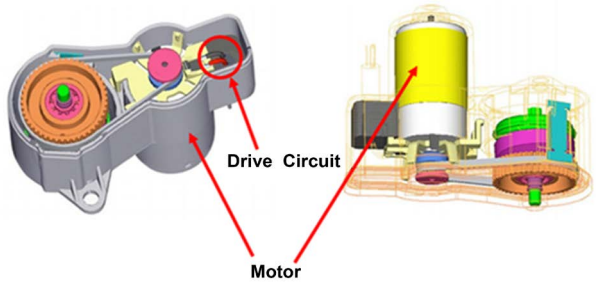

Figure 3. Electronic handbrake actuator of internal structure of motor.

the vehicle when the car parking continually or long time with the Engine worked.

2.2. Factors Affecting Vehicle Safety Reversing

There are many factors affecting vehicle safety reversing, including: driver's view, reversing speed, braking time, braking distance, driver's reaction time, etc. At present, most of the vehicles in the market are equipped with reversing radar or the car refit store install the radar, which can help the driver to judge and prompt safe reversing distance. But the accident is still frequent when reversing, mainly because the driver's reversing speed is too fast or mistakenly stepping on the gasoline throttle, reversing the distance after the alarm did not brake in time, causing the vehicle directly hit the person, vehicles or other obstacles.

For example, most reversing radar sets a safe distance of 1.5 m. The vehicle reversing speed is defined as V, the friction coefficient between wheel and ground is defined as μ, the friction force is defined as F, the speed after braking is defined as V_0, the braking time is defined as t, and the braking distance is defined as S. when electronic handbrake works, the motor output torque is constant. The deceleration of the vehicle is defined as a, results are shown in formulas:

$$S = Vt + 1/2\,at^2 \tag{1}$$

$$a = \frac{(V_0 - V)}{t} \tag{2}$$

$$f = mg\mu = ma \tag{3}$$

The final speed V_0 after braking is 0 (vehicle stationary state). According to statistics, the general reaction time of good driver is between 0.4 to 0.6 s. Most of the reactions were greater than 1 s when the driver was frightened, generally within 1.5 s, at this time prone to mistakenly step on the throttle phenomenon.

For two example, the first is delayed braking, and the second is mistakenly stepping on the accelerator.

The first example, a vehicle reversing speed of V (normally the reverse velocity is less than 6 km/h, can use the handbrake brake), the normal reaction time is T_1, braking time is defined as t_1, the braking distance is S_1, the braking deceleration is a_1. if delay brake that the reaction time is T_2 , the braking time is i_2. The braking distance is S_2, the braking deceleration of a_2. The safety distance is S(1.5 m). After braking, the distance from the obstacle to car is S_0. Results are shown in formulas:

$$\Delta T = T_2 - T_1 \tag{4}$$

$$S_1 = Vt_1 + 1/2\, a_1 t_1^2 \tag{5}$$

$$S_2 = Vt_2 + 1/2\, a_2 t_2^2 \tag{6}$$

$$S = S_1 + S_{01} \tag{7}$$

$$S = \Delta S + S_2 + S_{02} \tag{8}$$

Bringing ΔT into the formula, results are shown in formulas:

$$\Delta S = V \times \Delta T \tag{9}$$

Due to the use of electronic brake, the output torque of the motor is same in the above two cases, and the braking speed is constant, so the braking deceleration distance unchanged, braking time, braking distance is also unchanged. So S_1 and S_2 are equal. When the car reversing to safe distance that the critical point, system will be alarm, the driver quickly take electronic handbrake brake, the vehicle completely stopped, the vehicle and the obstacle distance S_{01} is in a critical state, which is safety. After the driver delayed operation, the vehicle began to brake after exceeding the safe distance of ΔS , and the vehicle collided with the obstacle before stopping

The second case, a vehicle speed is V (normal astern speed is lower than that of 6 km/h, electronic handed brake can be worked), defined as S is safety distance, defined as V_1 is the speed that step on the gas , defined as a_1 is acceleration , defined as t_1 is acceleration time, defined as S_1 is acceleration distance , defined as t_1 is acceleration time, defined as S_0 is car and obstacle distance. results are shown in formulas:

$$S_1 = Vt_1 + 1/2\, a_1 t_1^2 \tag{10}$$

$$S_0 = S - S_1 \tag{11}$$

If step on the gas, the speed of V_1 is more than 6 km/h, electronic brake failure, the driver could react, then step the brake pedal brake, this time at least

more than 2*S*, and the safety distance of only 1.5 m, In the case of 6 km/h speed, only 1 s will be move 1.67 m, so the car is already collided. Obviously, the accident is easy to happen when mistakenly stepped on the accelerator.

2.3. Design of Car Reversing Brake Auxiliary System

In order to avoid the above problems, design of car reversing brake auxiliary system. Considering the versatility of most vehicles on the market, the system uses single chip and control, the vehicle reversing radar and GPS module for monitoring vehicle reversing, reversing of vehicles by judging the safety distance to control the electronic accelerator pedal and an electronic handbrake actuating motor realize brake quickly and effectively.

2.4. System Scheme and Main Circuit

The system that hardware main consist of the STC12C5A60S2 microcontroller (dual serial data transmission board), ultrasonic radar monitoring circuit, GPS induction circuit, normally open and normally closed relay, electronic accelerator pedal, electronic handed brake executive motor. STC12C5A60S2 microcontroller have enhanced 8051 that MCU with the kernel, the system program without extending the data memory and program memory also can be a very good operation more complex program.

MCU include Flash program storage with 60 KB, and Integrated 128 B data memory [9]. STC12C5A60S2 single chip microcomputer is the core of the whole system. The ultrasonic radar monitoring circuit sends the measured signal back to the single chip microcomputer and analyzes the distance value by installing the probe at the tail of the vehicle. GPS induction circuit speed signal transmission to the microcontroller when vehicle reversing, the speed and monitoring distance and as the judgment condition. When the need for auxiliary braking, microcontroller through the normally closed relay switch off electronic accelerator control, through the normally open relay control electronic handed brake actuating motor operation.

The hardware block diagram is shown in **Figure 4**.

2.5. Ultrasonic Reversing Radar Circuit

The ultrasonic reversing radar circuit uses the ultrasonic pulse echo transit time method to realize the measuring distance, and calculates the distance between the vehicle and the obstacle according to the time difference between the transmitting ultrasonic wave and the received reflected wave and the corrected wave velocity [10]. The common reversing radar host in the market is used to be the ultrasonic reversing radar circuit, and the data output mode is TTL serial communication mode. When it is connected with the MCU, the reversing radar circuit data line UART_TX pin to connected with the single-chip RXD0 (P3.0) pin, to the reversing radar circuit grounding. Ultrasonic reversing radar circuit and SCM connection mode are shown in **Figure 5**.

2.6. GPS Speed Circuit

GPS speed circuit is selected to U-BLOX NEO-6M module. It is compact and amplifies the circuit, which is helpful for rapid communication with satellites. The module communicates with the microcontroller through the serial port, compatible with 3.3 V and 5 V level. The connection between GPS speed circuit and single chip microcomputer is shown in Figure 6. GPS module monitoring speed range: 0 - 1851.8 km/h. when it connected with the MCU, The GPS module RXD connected TXD1 microcontroller (P1.3) pin, and TXD connected RXD1 microcontroller (P1.2) pin.

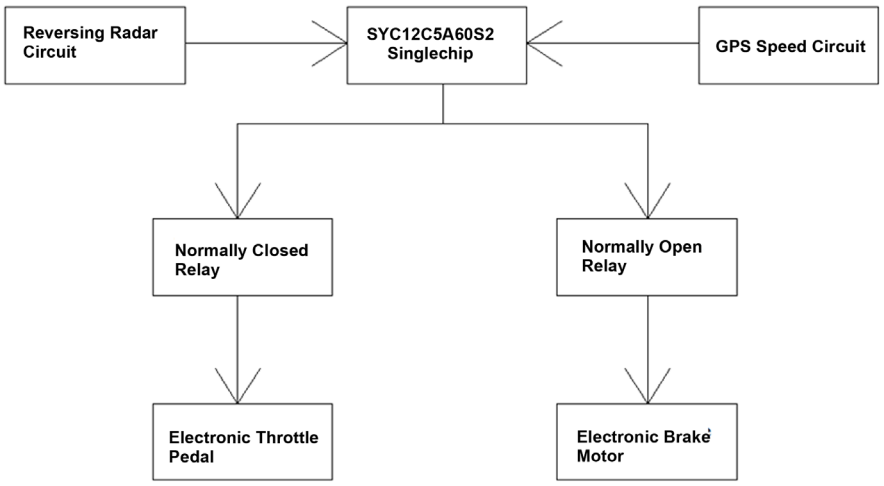

Figure 4. Hardware frame diagram of the system.

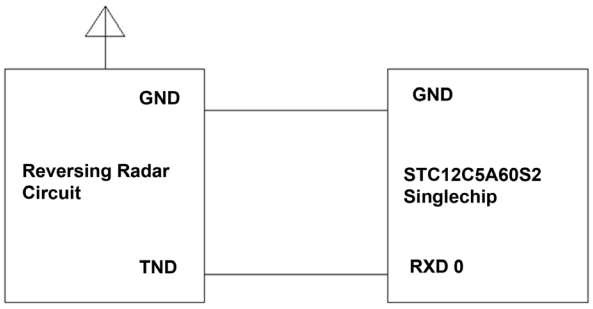

Figure 5. Ultrasonic reversing radar circuit and SCM connection mode.

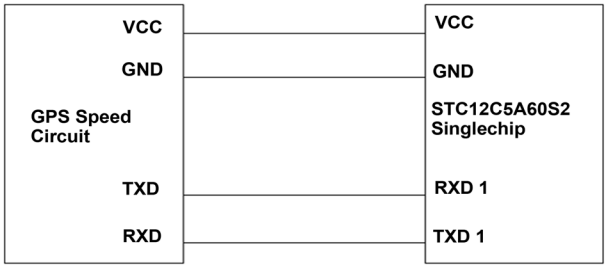

Figure 6. GPS speed circuit and SCM connection mode.

2.7. Normally Open/Normally Closed Relay

The hardware system though normally open relay control by SCM, adjust the working state of the electronic parking brake actuating motor, realize the parking function, and by controlling the normally closed relay with single chip microcomputer, the response state of the electronic accelerator pedal is adjusted to prevent the speed too fast when the car is reversing state. The working principle is shown in Figure 7.

The connection mode of relay is shown in Figure 8.

2.8. System Software and Control Flow

The system software is mainly compiler by KEIL Vision, hardware simulation using Proteus software, the simulation is completed, the microcontroller serial communication mode and connected to the computer, using the serial port assistant to send trigger code, check the system whether in accordance with the action by logic. After debugging, the written code conversion format will be written to the microcontroller. System control program flow shown in Figure 9.

2.9. Main Application Program

The system program is divided into three parts: The first part, will the numerical 16 hexadecimal conversion to decimal (e.g. 0 × 66) (102). Because the signal sent by the reversing radar is 16 hexadecimal, so it needs to transform to decimal. The second part, serial 0 and serial 1 interrupt function, used to receive distance and speed data sent from reversing radar and GPS module. The third part is main function. It is used to read the data, judging the opening and closing of the control relay and control the motor and electronic accelerator pedal to finish brake. The circuit diagram of STC single chip microcomputer is shown in Figure 10.

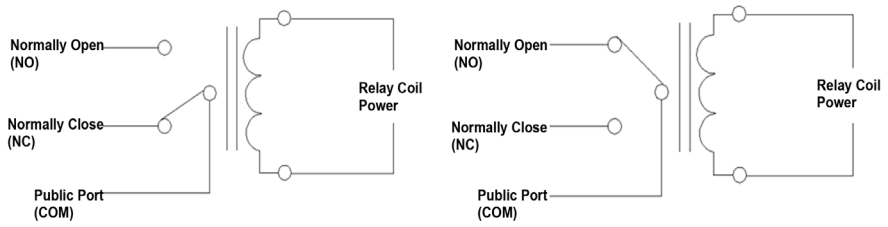

Figure 7. Working principle of normally open/normally closed relay.

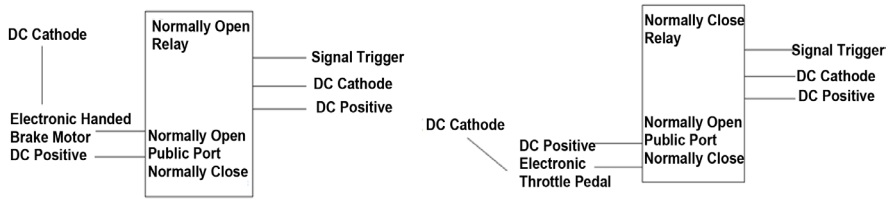

Figure 8. Connection mode of normally open/normally closed relay.

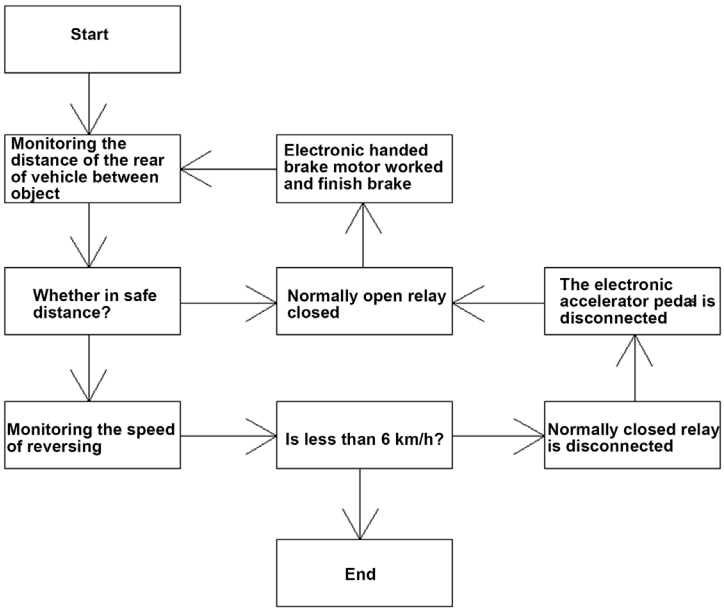

Figure 9. System program control flow.

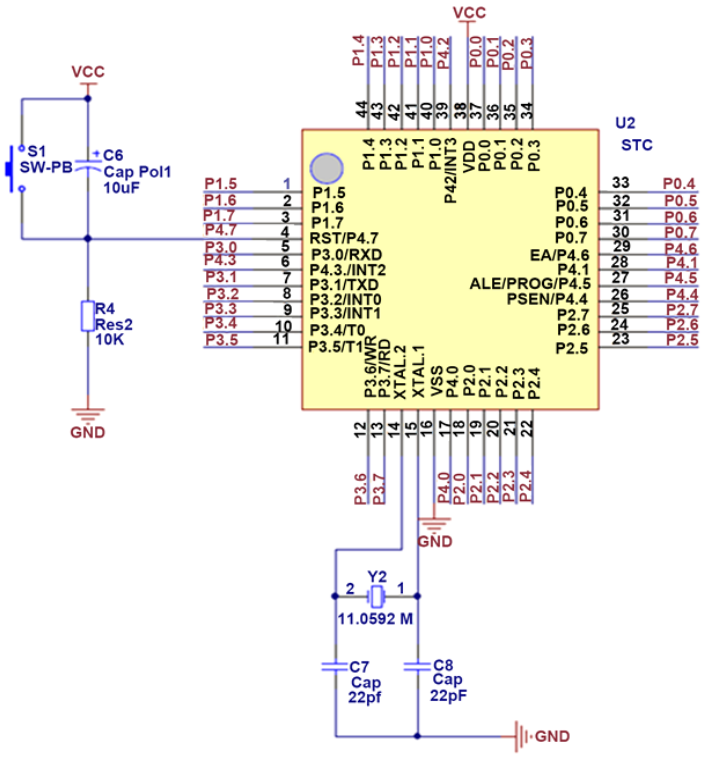

Figure 10. The circuit diagram of STC single chip microcomputer **Test verification.** Part of the program code is as follows: Char_Table; Digital tube segment code; Rece_datas; The data buffer is defined to received; Sun, temp_u2, tim; Transfer variable data; Data_count_fg; Receive data variable definition; TMOD = 0X01; Working with sixteen bit calculator mode; TH0 = (66535-tim)/256; Set timer Digital high initial value; TL0 = (66535-tim)%256; Set timer Digital low initial value; Void chuli(); Radar and GPS receiving data processing; Void alarm(); Relay action.

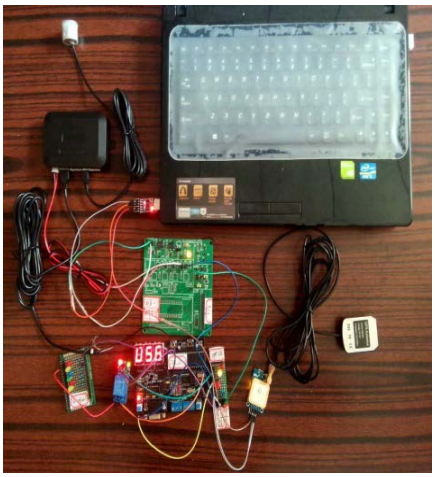

Figure 11. System test chart.

Figure 12. The received GPS message.

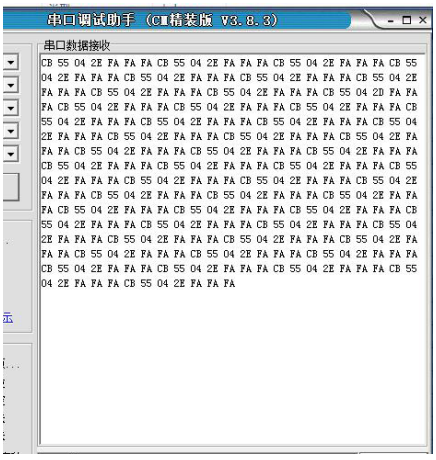

Figure 13. The received reversing radar message.

Through the test, will the single chip is connected with the reversing radar module, GPS module, relay. SCM connect notebook, using serial assistant to receive the message of reversing radar and GPS. The reversing radar probe placed away from the desktop or obstacle is less than the safe distance 1.5 m, the MCU will trigger signal sent to the normally open relay, normally closed relay, electronic parking brake and run after the motor is energized. When using serial assistant to simulate the distance between probe and obstacle is smaller than the safe distance, the control relay has the same effect. Simulation of driver mistakenly stepping on the accelerator or directly depresses the accelerator pedal, GPS speed is greater than 6 km/h, the MCU will sent signal to normally closed relay, electronic accelerator pedal power, made the speed dropped to a low speed state, combined with the reversing radar, ensure the vehicle reversing is safety. The test results are consistent with the design target of the system (**Figures 11-13**).

3. Conclusion

This paper analyzes the factors that influence the braking of automobile under the condition of reversing, and introduces design and development of vehicle reversing brake assist system. It uses STC12C5A60S2 to receive GPS speed signal and reversing radar signal, judges the safety state of the vehicle reversing, to achieve control of the accelerator pedal and brake motor, enhances the safety of vehicle reversing, and prevents vehicle accidents caused by drivers mistakenly stepping on the accelerator or delaying braking when the car reversing. It has important guiding significance for the optimization and intelligent development of vehicle braking system.

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