Design of automobile engine control system based on FlexRay bus

PAN Hui[1], WANG Yi[2]

(1. College of Electronics and Information, Guizhou University, Guiyang 550025, China;
2. College of Physics and Electronics Science, Guizhou Normal University, Guiyang 550001, China)

Abstract: FlexRay bus has become the standard of similar products and it will lead the direction of the development of automotive electronics control system for a long time. This paper proposes a design of automobile engine control system based on FlexRay bus. In order to improve the network rate, reliability and flexibility, it adopts high-performance MC9S12XF512 microcontroller of Freescale and FlexRay bus driver TJA1080 of NXP company, and it gives the overall circuit design and software design process of automobile engine control system. The design has the characteristics of simple hardware circuit, high reliability and good real-time performance. It offers a certain reference value for the development of FlexRay bus node of engine control system.

Key words: FlexRay; automobile engine; MC9S12XF512; TJA1080

CLD number: U464; TP273 **Document code**: A
Article ID: 1674-8042(2014)03-0064-05 **doi**: 10.3969/j.issn.1674-8042.2014.03.012

0 Introduction

With the rapid development of modern automobile electronic technology, the function of automobile has been increased continuously. More and more electronic systems are applied to the car, especially x-by-wire system, which promotes the development of vehicle bus and network technology. Traditional in-vehicle network systems such as local interconnection network (LIN) and controller area network (CAN) have been replaced by FlexRay bus owing to its advantages of time-triggered communication method, fault tolerance and high data rates. It can also integrate and co-exist with current network systems, including CAN, LIN, J1850 protocol, etc. FlexRay bus has become a new standard for vehicle bus communication among electronic devices. Nowadays, almost all the leading automotive, semiconductor and electronic systems manufacturers have become the members of the FlexRay Consortium, who provide their product solutions and applications for FlexRay to further quicken development[1-2].

As the heart of the car, engine has complex structure and parts, as well as poor working conditions. Thus it becomes easy that the engine malfunctions or the car's performance becomes poor. Automobiles can drive faster and faster, but it may cause some social problems, such as environmental problems, traffic jam and traffic accidents. Automotive electronic technologies have been developed in order to solve these social problems[3]. As the next generation automotive control and communication protocol, FlexRay has the characteristics of reliability, determinacy, fault tolerance and high data rate[4].

This paper describes the hardware and software designs of automotive engine control system based on high performance MC9S12XF512 microcontroller of Freescale and TJA1080 bus driver of NXP company. It simplifies the design of hardware circuit and increases the reliability of the automotive engine control system.

1 Automobile engine control system

The engine of electronic-controlled fuel injection vehicles is controlled by an electronic engine control system, whose main function is to control the air-fuel ratio, ignition and injection timing according to the collected engine signals to maintain the best working conditions. The core of engine of the electronic-controlled fuel injection vehicles is electronic control unit (ECU). According to the obtained signals from sensors, the ECU makes the decision after calculating and processing, then it outputs control signals to the actuators to accurately control the engine fuel injection volume, ignition timing and idle

* **Received date**: 2014-05-14
Foundation item: National Natural Science Foundation of China (No. 61262007), Guizhou Science and Technology Department School Cooperation Project (Qian Bureau No. [2013] 7001).
Corresponding author: WANG Yi (wyigz@126.com)

speed, which makes it possible for the generators to operate in optimum conditions.

For any kind of electronic control system, signal input divices, ECU and actuators are major parts, as shown in Fig. 1.

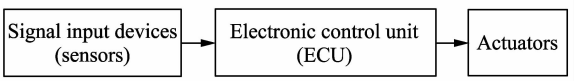

Fig. 1 Components of engine electronic control system

1.1 Signal input devices

Signal input devices for engine electronic control system are a variety of sensors, which are installed in various parts of the engine. By detecting parameters of engine running condition, it collects the signals of control system, converts them into electrical signals and transports them into ECU.

The sensors used in engine electronic control system are the core of automobile sensors that have a wide range, including speed sensor, temperature sensor, pressure sensor, flow sensor, knock sensor, throttle position sensor, gas concentration sensor, etc. The sensors provide the signals of engine operating condition to ECU which controls the engine's operating condition to increase engine power, lower fuel consumption, reduce emissions and detect fault, etc.

1.2 Electronic control unit (ECU)

ECU is an integrated electronic control device, which is also an indispensable automobile microcontroller in pratice. Its function is to receive information from the sensors and the inputs of control switches. According to the stored programs and data, it outputs control parameters after fast and accurate processing, computing and judgment, then it performs various predefined motions to control actuators. To make real-time control for fuel injection quantity, injection timing and ignition point, it keeps the engine in top working condition.

ECU is the control center of engine electronic control system that processes analog and digital signals transmitted by multiple sensors when the engine is in operation, then it determines the current operating state of the engine based on these signals and outputs corresponding control signals after CPU calculation to control the engine operation.

1.3 Actuator

Actuator is the executing agency of control system, and its function is to receive ECU control instructions, to complete specific control action, and then to make the engine in optimum working condition. The actuators of electronic control system of engine have electric fuel pump, fuel injectors, ignition coils, idle speed control valve, canister solenoid valve, etc.

In the control process, the control signals transmitted by ECU are converted into some sorts of mechanical or electrical movements by the actuator which leads to the change of the engine operation parameters to complete control function.

2 System hardware design

The hardware part is designed to achieve efficient and reliable automobile engine control system. The system mainly consists of communication control module and bus driver module. The communication control module is mainly responsible for collecting data signal, encoding the signal, and then sending the data to the FlexRay bus for each sub-node to recognize and receive it. Based on user-defined identifier, the bus driver module receives data that is transmitted on the FlexRay bus, decomposes them, and then sends control signals to the driving device to control the engine.

2.1 General design of control system

In early days, each electronic control system was designed independently. Today's automobile has various functions which could be completed by multiple electric systems. Therefore, the fundamental architecture of the integrated electronic systems of an automobile is important that is be designed in order to optimize the total function, cost and productivity[5].

There are mainly two ways of FlexRay node architecture: micro control unit (MCU) + communication control (CC) + bus driver (BD) and MCU + BD[6]. In this paper, MC9S12XF512 microcontroller is adopted and FlexRay bus driver TJA1080 is the core of design control circuits. The overall system block diagram is shown in Fig. 2.

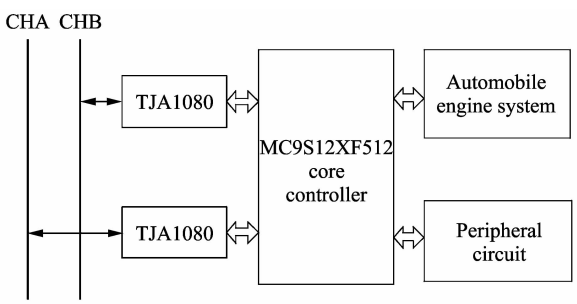

Fig. 2 Block diagram of overall system

The core controller adopts the Freescale 16-bit microcontroller MC9S12XF512, which provides embedded FlexRay controller, which makes the system design greatly simplified and also improves the effi-

ciency and reliability of the system. MC9S12XF512 is mainly responsible for the acquisition of automobile engine signal while processing and then sends data to the FlexRay bus via the FlexRay bus driver. In this system, FlexRay bus driver TJA1080 is a high-speed FlexRay transceiver. It is primarily intended for communication systems from 1 Mbit/s to 10 Mbit/s, and provides an advanced interface between the protocol controller and the physical bus in a FlexRay network. The TJA1080 provides differential transmitting capability to the network and differential receiving capability to the FlexRay controller[7].

2.2 Design of air-fuel ratio control system

The air-fuel ratio control of engine ECU is completed by controling fuel injection quantity. The fuel injection quantity of engine electronic control system is controlled by feedforward control and closed-loop control methods. Engine electronic control system uses the combination of both methods to achieve constant air-fuel ratio control of engine under steady-state operation. Feedforward control method determines the fuel injection quantity based on the information about the current condition and other factors of the engine. Feedback control method compensates for the basic injection quantity according to the oxygen sensor signals. Thus ECU achieves optimal control of air-fuel ratio through precise control of injection volume. The block diagram of air-fuel ratio control algorithm is shown in Fig. 3.

The feedforward control module controls the solenoid fill valve according to signals of rotating speed ‖and cooling water temperature to make the engine have a fast response , which is mainly used under the idling condition, starting condition, acceleration and deceleration conditions of the engine. The fuzzy control module is used under steady state condition to achieve closed-loop control of the air-fuel ratio. And the intelligent harmony module is used to determine the control mode according to the sensor parameters of system feedback.

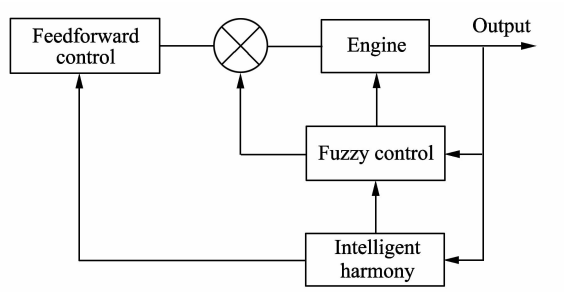

Fig. 3 Block diagram of air-fuel ratio control algorithm

2.3 Hardware design of ECU

The ECU hardware design follows the principle of modular design so as to ensure the design, debugging and modification of the ECU are clearer and simpler[8]. The ECU of engine electronic control system mainly includes sensors, ECU control module and actuators, and the structure is shown in Fig. 4. The input signals collected by sensors mainly include rotating speed signal, vehicle speed signal, temperature signal, oxygen sensor signal, etc. The actuator mainly consists of fuel pump, fuel injector, ignition coil, idle speed control valve, and so on, which realizes the control of fuel injection quantity, ignition timing and idling speed of engine.

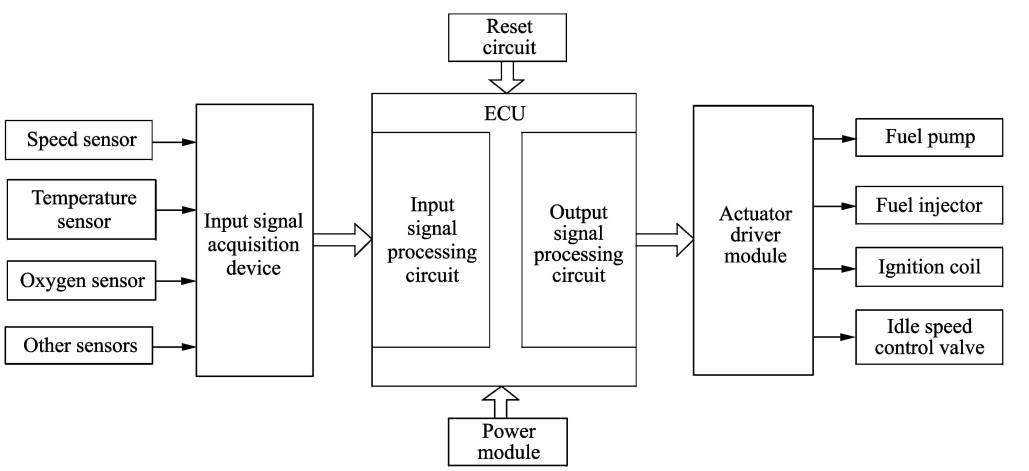

Fig. 4 Hardware design of ECU

ECU is a node controller, whose major function is to receive the engine condition signals collected by sensors of the engine to convert the engine operating condition parameters required by the control al-

gorithm to digital quantity which can be processed by CPU, then it judges the engine's working conditions according to the input quantity and finally converts the control output quantity processed by CPU to the driving volume of actuator according to the corresponding control commands sent by intrinsic control algorithm.

3 System software design

Software design is the key of the system. In order to improve reliability and comprehensibility, the software part of the system is modular in design. Each module is connected to form a complete software system[9]. The automobile engine control system includes FlexRay initialization, sending and receiving messages, data processing and other modules.

The detailed FlexRay data communication process is shown in Fig. 5. Initialization is the process of establishing single chip operating ambient. The main program module is the main past of the system software, whose main task includes system initialization, signal acquisition and processing, data communication and transmission.

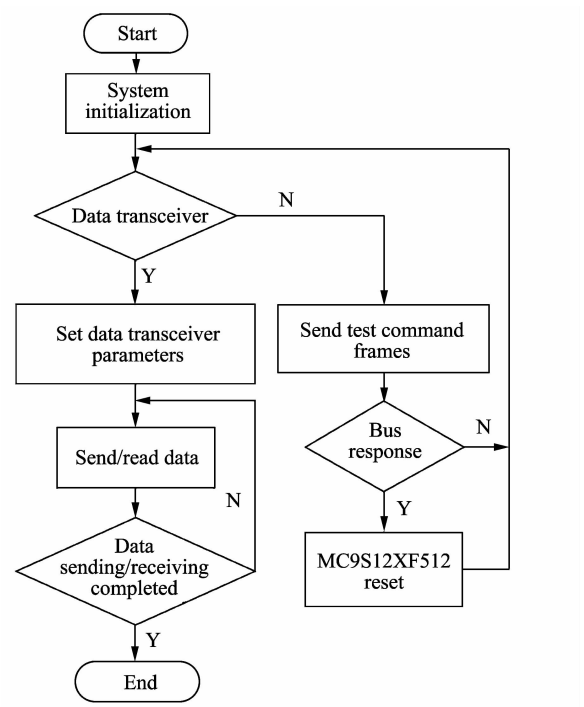

Fig. 5 Flow chart of data communication

The software design of ECU is to calculate control quantity based on the acquired condition parameters of engine, to choose reasonable injection quantity and fuel injection time according to the current condition information, and to realize the best overall properties of engine under various conditions and running status.

The flow chart of ignition and fuel injection program is shown in Fig. 6.

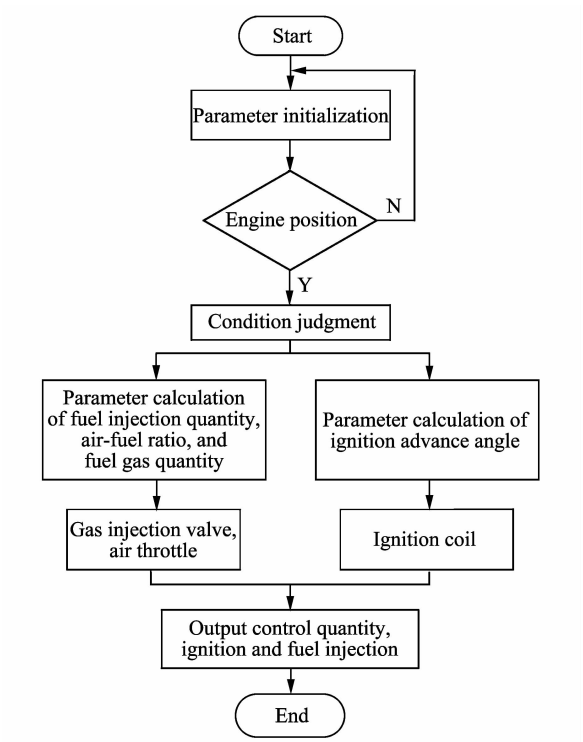

Fig. 6 Flow chart of ignition and fuel injection progarm

4 Conclusion

The hardware and software designs of automobile engine control system are discussed in detail and the hardware and software of the FlexRay ECU are developed, respectively. Hardware design is given based on the mainstream of FlexRay communication unit MC9S12XF512 single-chip. The structure of engine control system and its peripheral circuits are designed. Software is designed based on modular ideology, which improves the reliability and maintainability of the system. The paper concludes that automobile engine reliability will be improved by using FlexRay bus. The circuit can also be used in other corresponding power and electronic control systems, and has a certain practical value.

References

[1] FlexRay Union. FlexRay-Protocol Specification V2.1. [2014-03-12]. http://www.flexray.com.

[2] FlexRay Union. FlexRay-EPL-Specification V2.1. [2014-03-12]. http://www.flexray.com.

[3] ZHUANG Jiang-li. FlexRay bus networking and its application in the hybrid power bus. Beijing: Beijing Jiaotong University, 2012.

[4] ZHANG Zhi-wen, CHEN Xin, LV Xun-hong. The design of internal bus communication node of a distributed

flight control computer. Electronic Technology Application, 2011, 37(11): 40-43.
[5] Furukawa Y, Kawamura S. Automotive electronics system, software, and local area network. In: Prceedings of the 4th International Conference on Hardware/Software Codesign and System Synthesis, Seoul, 2006: 2.
[6] Wang C C , Sung G N, Wang C I, et al. Physical layer design for ECU nodes in flexray-based automotive communication systems. In: Digest of Technical Papers of International Conference on Consumer Electronics, Las Vegas, 2009: 1-2.
[7] ZHANG Ji-wei, WANG Xu-guang, GUAN Zhi-guang. Research on power measurement and loading control system of automobile engine test stand. In: Procedings of 2010 International Conference on Computer, Mechatronics Control and Electronic Engineering (CMCE), Changchun, 2010: 478-481.
[8] Pop T, Pop P, Eles P, et al. Timing analysis of the flexray communication protocol. Real-time Systems, 2008, 39(1/2/3): 205-235.
[9] Inseok P, Myoungho S. FlexRay network parameter optimization method for automotive applications. IEEE Transactions on Industrial Electronics, 2011, 58(4): 1449-1459.

基于 FlexRay 总线的发动机控制系统设计

潘 辉[1], 王 义[2]

(1. 贵州大学 电子信息学院, 贵州 贵阳 550025; 2. 贵州师范大学 物理与电子科学学院, 贵州 贵阳 550001)

摘 要: FlexRay 总线已经成为同类车载网络总线的标准并将在未来很长时间引领整个汽车电子控制系统的走向。本文分析了汽车发动机控制系统的构成, 提出了一种基于 FlexRay 总线的控制设计。为了提高该控制系统的通信速率、可靠性和灵活性, 文中采用飞思卡尔公司的高性能单片机 MC9S12XF512 和恩智浦公司的 FlexRay 总线收发器 TJA1080, 并完成了电路整体设计方案及软件设计流程。本文设计的发动机控制系统具有硬件电路设计简单, 可靠性高和实时性强的特点, 对汽车 FlexRay 总线的发动机控制系统节点开发具有一定的参考价值。

关键词: FlexRay; 汽车发动机; MC9S12XF512; TJA1080

引用格式: PAN Hui, WANG Yi. Design of automobile engine control system based on FlexRay bus. Journal of Measurement Science and Instrumentation, 2014, 5(3): 64-68. [doi: 10.3969/j.issn.1674-8042.2014.03.012]