Design of Dual MCU Vehicle Control Unit Based on Electric Vehicles to Respond to Control Failure

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Abstract. The Vehicle Control Unit (VCU) is the core component of the entire car. It is responsible for collecting the accelerator pedal signal, brake pedal signal, gear signal and other component signals, and makes corresponding judgments based on the vehicle status to control the next controllers of each component of the layer act to drive the electric vehicle. This article introduces the overall system structure of the electric vehicle and the structural characteristics of the Vehicle Control Unit, analyzes the benefits of the dual MCU Vehicle Control Unit to the electric vehicle, and finally establishes the corresponding detection and response methods when various possible failures occur. The detection and response mechanism uses the main and auxiliary dual MCUs as the control core and cooperates in processing. When the main MCU fails, the auxiliary MCU takes over the control to avoid the uncontrollable safety problems caused by the control of the entire vehicle when the single MCU fails. The dual MCU controller uses the main and auxiliary differentiated design, and the functional design of the main and auxiliary MCUs is based on the functional modularity idea. After the main MCU meets the functions of vehicle control and other functions, the sensor signal detection and other functions are added to the auxiliary MCU. A dual MCU Vehicle Control Unit based on electric vehicle response to control failure is presented.

1. Introduction

In recent years, with the continuous development of China's technology, many high technologies have been applied to the field of automotive research and development. With the continuous loss of energy in China, the development and application of new electric vehicles is a very popular technology. The Vehicle Control Unit used in traditional electric vehicles is generally a single MCU architecture, and the system stability and safety of this architecture are not ideal. [1] The main parts and foundations need to be constantly reformed and improved by the design principles.

First of all, the overall safety of the dual MCU electric Vehicle Control Unit hardware design must be ensured, because the safety performance of the car is the first and most basic link. In the process of designing the Vehicle Control Unit hardware, certain It should be based on the safety principle of the system as a standard, and at the same time, a reasonable design should be carried out in accordance with the design requirements specified by the state. The dual MCU in the design of the dual MCU pure electric Vehicle Control Unit introduced in this article mainly refers to the independent MCU unit and MCU communication. When the main MCU fails or other problems occur, the auxiliary MCU can independently determine the critical parts of some computing aspects, thereby ensuring that the auxiliary MCU can respond to the failure of the main MCU. The function of protecting the safety of
the entire system. Therefore, the application of MCU pure electric Vehicle Control Unit hardware equipment is a key step to ensure the safety performance of pure electric vehicles.

2. Overview of electric vehicle systems

2.1 Electric vehicle system structure composition
Pure electric vehicles only rely on the electric energy provided by the power battery pack as a power source to drive the motor to rotate, thereby providing power for the entire vehicle. The structure of a pure electric vehicle mainly includes a motor drive system, an energy management system, a vehicle control unit, a charging control unit, a power conversion device (DC / DC), and an instrument display system. Its basic structure is shown in Figure 1. The battery and management system are the energy source of the vehicle; the motor and control system provide power for the vehicle; the Vehicle Control Unit (VCU) collects gear signals and pedal signals to control the discharge of the battery and the operation of the motor; the charger is the battery Group charging; the motor control system converts the DC high-voltage power of the battery pack into AC power to drive the motor to rotate,[2] providing power for the entire vehicle; the instrument provides the driver with vehicle operating status information.

![Figure 1: The basic structure of an electric vehicle](image)

2.2 Structure of electric Vehicle Control Unit
VCU is a dispatch control center for electric vehicles, which is responsible for communicating with other vehicle components and coordinating the operation of the entire vehicle. The VCU system structure is shown in Figure 2. It mainly includes power circuit, digital input / output module, analog input module and CAN communication module. The power module takes power from the on-board battery. The signals received by the switch input module mainly include key signal, gear signal and brake switch signal; the switch output signal is mainly a control relay, which has a slightly different meaning in different vehicle systems, Under normal circumstances, such as water pump relay, fan relay, EV relay and PTC relay. The analog input module collects accelerator pedal and brake pedal opening signals and battery voltage signals. The CAN module is responsible for communication with other equipment of the vehicle. The main equipment includes the motor controller (MCU), battery management system (BMS), display instrument, DC / DC module and charger.
2.3 Main functions of VCU

① Vehicle driving control: collect driver's driving needs and manage vehicle power.

② Network management: monitor communication network, information scheduling, information summary, and act as a gateway.

③ The auxiliary drive of the instrument monitors and displays the vehicle status.

④ Fault diagnosis processing: Diagnose and detect the faults of sensors, actuators and other components of the system and carry out corresponding fault processing, and display faults in real time.

⑤ Energy management and online configuration and maintenance.

⑥ Power distribution: Calculate the distribution of motor power through comprehensive vehicle information including battery SOC, battery pack temperature, motor temperature, etc., and perform vehicle drive and braking energy feedback control. [3]

⑦ Other driving assistance functions, such as anti-slip car control when starting on a hill.

3. Research significance of dual MCU Vehicle Control Unit

Compared with the traditional single MCU Vehicle Control Unit, the design and manufacture of the dual MCU Vehicle Control Unit is more complicated, but it can make the electric vehicle obtain more superior performance and improve its safety, and can avoid many shortcomings of the single MCU Vehicle Control Unit, for example, when the brake pedal or accelerator pedal fails, the vehicle may lose control.[4] There are the following three research significances for studying the Vehicle Control Unit based on the main and auxiliary dual MCUs of electric vehicles:

(1) Test and respond to various possible failures

Use an inductive analysis method to conduct functional safety analysis, list the various situations of potential Vehicle Control Unit control failures, and summarize them, classify their severity levels, and determine the corresponding detection methods for each severity level of failure and coping style.

(2) Avoid the failure of the main MCU

In order to achieve the design goals of the Vehicle Control Unit, the dual MCU architecture is adopted in the system architecture design. The main and auxiliary MCUs are selected separately, and the main and auxiliary MCUs are designed with independent power supply circuits. The master-slave architecture mode is adopted between the master and slave MCUs, that is, the master MCU is responsible for signal collection, logic operation and the sending of control commands to control the normal work of the vehicle, and the slave MCU is responsible for monitoring the master MCU and sensor signals to determine whether the master MCU is working. There are exceptions, and when the
main MCU fails, it will take over the basic functions of the main MCU in time to ensure the normal operation of the vehicle's basic control functions and improve safety. [5]

(3) Reduce the coupling degree of the system

The design of the main and auxiliary MCU, with the main MCU meeting the functional requirements of vehicle control, the auxiliary MCU realizes the sensor signal detection and the main MCU failure monitoring function, and the basic normal control function after taking over as the basic design idea, to achieve the main and auxiliary MCU function With the decoupling between the functions, the design of the Vehicle Control Unit is implemented with the corresponding functional modular design.

4. Design idea of dual MCU Vehicle Control Unit

For electric vehicles, the Vehicle Control Unit is equivalent to the brain of the entire vehicle. Therefore, the Vehicle Control Unit has many tasks and very important positions in the process of running the vehicle. The functions of the Vehicle Control Unit mainly include the following points. The first is the ability to discern the road conditions on the driving road, and the reasonable analysis ability when the entire car fails, and it can also handle the faults of the car at different levels, and the Vehicle Control Unit will also The entire vehicle is controlled in various situations during driving, and the Vehicle Control Unit can effectively analyze all the drivers' ideas and intentions during driving, helping the driver to more easily during driving To control the car, the Vehicle Control Unit can also calculate the distance and route of the trip, so that the driver can reasonably control how far he has to reach his destination during driving. [6] Finally, the ability of the Vehicle Control Unit is to have safety management capabilities and the ability to optimize the management of the internal energy of the car, ensuring that the car is effectively controlled from the inside to the outside, making the driver's Safety performance is greatly improved. In the design process of the electric vehicle, the Vehicle Control Unit must combine the overall structure and frame requirements of the electric vehicle, so that the various designs of the Vehicle Control Unit can be more reasonable and the functions are more comprehensive. In the design process of the controller hardware of the electric vehicle, it must also be combined with the car's own structural framework for reasonable design, and the internal circuit design of the MCU selection and so on must also be paid attention to. Only in this way can the various functions of the entire hardware structure meet the standards, so that the overall safety performance of the electric vehicle is guaranteed.

For the Vehicle Control Unit, the MCU is the most basic and core part of the Vehicle Control Unit. The main task of the MCU is to collect, process, and calculate the data, which can improve the Vehicle Control Unit during use. The reliability of this article is to explore the hardware design of the electric Vehicle Control Unit in dual MCUs. Therefore, there are two main MCU and auxiliary MCU in the design process. The main MCU is responsible for the signal collection, processing and calculation functions, and then the effective control of the corresponding control instructions on the data of the calculation results according to specific logic, so as to achieve the expected function is up to standard. The function of the auxiliary MCU is to diagnose the fault, and monitor the operation of the main MCU through various signal data. When the main MCU is not faulty, the auxiliary MCU can continue to collect various data, but the collected data is the main data during the driving of some cars. The calculation and corresponding implementation of these key signals can ensure that the vehicle continues to drive safely in the event of a failure of the main MCU. [7]When the main MCU fails, the vehicle system will actively turn off the signal transceiver, so that the auxiliary MCU completely replaces the main MCU to perform various data control during the entire vehicle driving process. All in all, the dual MCUs perform security checks on all data of the entire car and perform calculation processing to ensure effective control under safe conditions and ensure the normal operation of various parts of the car. The application and implementation of dual-MCU electric Vehicle Control Unit hardware can effectively improve the safety performance of pure electric vehicles during driving and use,[8] which not only ensures the safety of pedestrians, but also improves the use of vehicles. Efficiency, the basic design idea of the dual MCU Vehicle Control Unit is shown in Figure 3:
5. Design scheme of dual MCU Vehicle Control Unit

The functional modules of the Vehicle Control Unit are mainly divided into: single chip microcomputer module, power module, sensor module, transmission module and drive module. The main MCU is responsible for signal processing and control of the vehicle during normal operation, and the auxiliary MCU is responsible for detecting the work of the MCU and the sensor. In the state, when an abnormality is found, the auxiliary MCU takes over the processing and control of the vehicle signal, and if necessary, disconnects the circuit power supply in time.[9] Through the Altium Designer hardware design platform, the hardware circuit of each functional module is designed, and the final PCB board design work is completed. The 3D modeling of specific PCB circuit board design is shown in the figure:

![3D model diagram of the main MCU circuit board](image)

![3D model diagram of auxiliary MCU circuit board](image)
As shown in the schematic diagram of the MCU circuit, the Freescale K60 chip is used as the main MCU, and the Freescale MC9S12XE chip is used as the auxiliary MCU.

![Schematic Diagram](image)

**Figure 5**

6. **Conclusion**

Compared with the traditional single MCU Vehicle Control Unit, the design and manufacture of the dual MCU Vehicle Control Unit is more complicated, but it can make the electric vehicle obtain more superior performance and improve its safety, and can avoid many shortcomings of the single MCU Vehicle Control Unit, for example, when the brake pedal or accelerator pedal fails, the vehicle may lose control. The design of the complete vehicle controller for the dual MCU that controls the failure should adopt embedded development of the dual MCU complete vehicle controller, the function is modular, the auxiliary MCU function module reflects a certain difference from the main MCU, and the main and auxiliary MCU adopt the master and slave Architectural mode, that is, the main MCU is responsible for signal collection, logic operation and sending of control instructions to control the normal work of the vehicle, and the auxiliary MCU is responsible for monitoring the signals of the main MCU and sensors to judge whether the working status of the main MCU is abnormal, and taking over the basic functions of the main MCU in time when the main MCU fails to ensure the normal operation of the vehicle's basic control functions and improve safety.

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