Design of Electric Drive System of Electric Vehicle Based on CAN Bus

Yingshun Wang*
Guangdong University of Science &Technology, Dongguan, Guangdong, 523083, China

*Corresponding author: 279397189@qq.com

Abstract. At present, the transmission system of pure electric vehicle is a single engine transmission system, which has many similarities with the design of diesel locomotive. Because it has too many similarities with diesel locomotive design, its structure is relatively stable and it is easy to produce on the original production line. In this paper, the overall design, software and hardware design of electric drive system of electric vehicle based on CAN (Controller Area Network) bus are presented, and the system structure diagram, hardware circuit diagram and software program block diagram are drawn, and detailed explanation is given. At the same time, considering the harsh working environment and serious electromagnetic interference of the vehicle-mounted intelligent driving system, this paper also designs the anti-interference of the electric drive system of the electric vehicle to ensure the stable and reliable operation of the system.

Keywords: CAN bus; Electric vehicles; Electric drive system

1. Introduction
Electric vehicles refer to vehicles which are powered by on-board power supply and driven by motors and meet the requirements of road traffic and safety laws and regulations. The progress of electric drive technology based on power electronics provides an advanced material basis for the development of electric vehicles; The rise and development of mechatronics technology has provided rich technical experience for the evolution of the typical mechanical product, fuel automobile, towards mechatronics [1-2]. The electromechanical integration configuration mode and control method of electric vehicles are still in the stage of blooming, which is neither mature nor finalized. All countries in the world devote themselves to the development of electric vehicles.

CAN(Controller Area Network), which is one of the most widely used field buses in the world, is a serial data communication bus developed by Bosch Company of Germany in the early 1980s in order to solve the communication between the huge electronic control devices in modern automobiles and reduce the ever-increasing signal lines. CAN bus is a field bus with high communication rate and high reliability, which is widely used in automobile electronic control devices. Using CAN bus can reduce the quality of wire harness and improve the reliability of communication between automobile electronic control units [4]. In this paper, CAN bus technology is applied to the electric drive system of electric vehicles, and universal expansion unit is adopted to solve the problem of circuit design.
complexity of electric control system of electric vehicles, and the information of each electric control unit is optimally combined to realize full information sharing, so as to improve the performance of electric drive system of electric vehicles.

2. Characteristics of CAN bus

Electric vehicle is a high-tech product integrating computer technology, communication technology, electronic technology, new material technology, etc. Its structure is complex, and there are many components that need interaction but are relatively independent. Moreover, the vehicle environment is harsh, there is strong interference, and the reliability of using analog quantity is not high. Advanced and efficient control architecture can make the data exchange among various systems of electric vehicles meet the requirements of simplicity, rapidity, high reliability, strong anti-interference ability, good real-time, and strong system error detection and isolation ability. Advanced computer technology and CAN bus technology integrate intelligent control, signal acquisition, data processing and communication, and have good real-time control, which can realize intelligent vehicle control and effective integration of multi-sensor information.

CAN belongs to the field bus field, and it is a serial communication network that effectively supports distributed control or real-time control. CAN bus is widely used in industrial control field thanks to its own technical characteristics [5].

Specifically, it includes the following points:

1. It can transmit and receive data in several ways, such as point-to-point, point-to-multipoint and global broadcasting, only through message filtering, without special "scheduling".

2. Communication mode is flexible. CAN works in multi-master mode, and any node in the network can actively send information to other nodes in the network at any time, regardless of master and slave and without node information such as site address.

3. CAN adopts non-destructive bus arbitration technology. When multiple nodes send information to the bus at the same time, the node with lower priority will voluntarily quit sending, while the node with the highest priority can continue to transmit data without being affected, thus greatly saving the bus conflict arbitration time, especially in the case of heavy network load.

4. Short frame format communication has short transmission time, low interference probability and excellent error detection effect. The maximum number of bytes per frame is 8, which can meet the general requirements of control command, working state and test data in general industrial fields. At the same time, 8B will not occupy too long bus time, thus ensuring the real-time communication.

5. Each frame of CAN information has CRC check and other error detection measures to ensure the reliability of data communication.

3. Design requirements of electric drive system

According to the principle of vehicle dynamics, the electric drive system of electric vehicle must meet the dynamic characteristics of the vehicle. The dynamic performance indexes of the vehicle mainly include: initial acceleration $a_v$, rated speed $v_r$ and maximum speed $v_{max}$. These three indexes are the most basic design requirements of the electric drive system of electric vehicle, and the electric drive system meeting these requirements can work normally under other working conditions [6].

According to the characteristics of the automobile [7], the power $P_{v_{max}}$ required when the automobile runs at the maximum speed $P_{v_{max}}$ (km/h) is:

$$P_{v_{max}} = \frac{1}{Z_T} (k_1 A / c_1 + k_2 m / c_2) v_{max}$$

(1)

In which: $Z_T$ is transmission efficiency; $c_1, c_2$ are the speed coefficients under different resistances, respectively. The corresponding maximum speed is:
In which \( U \) is the main reduction ratio; \( R \) is the wheel radius.

In order to start the electric vehicle quickly, it is hoped that the starting torque will be large. At this time, the battery must provide a large working current, which causes the voltage of the battery to drop and affects the effective travel of the electric vehicle [8]. Therefore, the starting current of the motor should be limited. When the starting torque is insufficient, it should be met by the transformation of the main transmission ratio of the automobile, namely:

\[
NTst = IUkZT \quad (2)
\]

In which:

\( stT \) is the torque acting on the wheel;
\( k_5 \) is the motor overload multiple;
\( I_N \) is rated current of motor.

4. Schematic design

4.1. Hardware design

4.1.1. Motor model. The frequency conversion on the rotor side is basically that the actual rotating rotor circuit is converted into the static equivalent rotor circuit, which can realize the frequency conversion. The static rotor and the stator are the circuits of frequency \( f_1 \), the frequency of the equivalent circuit is that of the rotating rotor of \( f_2 \). When the rotor is stationary, \( s = 1, f_2 = f_1 \). Therefore, the numerator and denominator of the rotor current in actual operation expressed by the following formula are divided by the slip \( s \). During conversion, the rotor current is consistent because the frequency cannot be changed, so it is inferred that the magnetomotive force is unchanged.

Frequency calculation formula [9]:

\[
\dot{J}_{2s} = \frac{\dot{E}_{2s}}{R_2 + jX_{2s}} = \frac{s\dot{E}_{2s}}{R_2 + jX_{2s}} \quad (4)
\]

Obviously, it can be concluded that the rotor current value and its phase have not changed after equivalent conversion, so it is considered that the electromagnetic effect is consistent. In the later calculation, not only the parameters related to \( f \) should be changed, but also the equivalent rotor resistance \( R_2 \) should replace the rotor resistance \( R_2 \) before conversion. The equivalent circuit after frequency conversion is shown in Figure 1:

**Figure 1** Stator and rotor circuits of asynchronous motor after rotor winding frequency conversion

The model current of the motor at rest and rotation has not changed, only one additional resistance is needed. By contrast, it can be concluded that the electric power on this resistance is the actual mechanical output power of the motor. By matching the required power of the motor with the equivalent circuit, the required power can be deduced, and other parameters of the motor can be obtained. Finally, the voltage and current that the frequency converter needs to output can be obtained.
4.1.2. Interface circuit design. In the system, the CAN controller SJA 1000 produced by Philips company is adopted, which is completely compatible with the CAN controller PCA82C200 in hardware and software, and CAN complete all functions of the physical layer and data link layer of the CAN bus. The internal RAM of SJA 1000 is composed of groups and message buffers [10]. The sending buffer and the receiving buffer share a CAN address of 16H-18H, which consists of three units and CAN store a complete message to be sent or received on the CAN bus. In addition, SJA 1000 has a 64-byte extended receive buffer (REFIFO), which is larger, and the CPU can process one message while continuing to receive other messages.

In order to further improve the anti-interference ability of the system, an isolation circuit composed of a high-speed isolation device 82C250 is added between the controller SJA 1000 and the transceiver PCA82C250, and the power supply adopts a DC-DC converter. The hardware circuit design of CAN interface is shown in Figure 2.

![Figure 2 Hardware circuit design of CAN interface](image)

The purpose of using PCA82C250 is to increase the communication distance, improve the instantaneous anti-interference ability of the system, protect the bus, reduce radio frequency interference, and realize thermal protection. PCA82C250 allows the highest communication speed up to 1 Mbps and the maximum number of nodes up to 110 nodes. It CAN make the system open and flexible, even if the CAN bus can freely increase or decrease controller nodes without requiring all nodes and their application layers to change any software and hardware.

4.1.3. State acquisition part. Hall current sensor, Hall voltage sensor and temperature sensor are mainly used. The former mainly involves rivers and large current collection. When the primary and secondary magnetic fields reach equilibrium, the following relationship exists [11]:

\[ I_s \cdot N_s = I_p \cdot N_p \]  

(5)

In which:
- \( I_s \) — Secondary current, A;
- \( N_s \) — Secondary coil turns;
- \( I_p \) — Primary current, A;
- \( N_p \) — The number of turns of primary coil is generally 1.

Hall voltage sensor is similar to the former in principle. It connects a resistor with large resistance in series in the measured voltage loop, and then measures the current flowing through the resistor by Hall current sensor, so that an output signal proportional to the measured voltage can be obtained. Because the measuring current is small, the number of turns of the primary coil of Hall voltage sensor is generally large [12].
Figure 3 Temperature detection circuit

Thermistor temperature sensor is commonly used for temperature detection, which is mainly used for temperature measurement in the temperature range of (-200~500)℃. It has the advantages of low price, stable performance and easy installation. A thermistor is used as a temperature sensor in the electric brake, as shown in fig. 3. In the figure: J6 is the interface of thermistor; C33 is the filter capacitor; R13 is a voltage dividing resistor.

### 4.1.4. System reliability design

Because of the wide temperature range (-45 ~ 100℃), strong electromagnetic interference and other electronic noise, and harsh environment, to ensure the reliability of the system running in the car, it is necessary to improve the fault tolerance and anti-interference ability of the network structure itself.

In the design, the method of combining software and hardware is used for anti-interference. Electromagnetic compatibility design is adopted in hardware, which focuses on dealing with the interference caused by electrostatic field, magnetic field and transmission lines and circuits. Filtering, decoupling, isolation, shielding and grounding are adopted, and power supply voltage detection, watchdog and other circuits are added. Specific measures are as follows.

1. The transmission line adopts shielded twisted pair.
2. Timeout reset with watchdog timer.
3. A photoelectric isolation circuit composed of a high-speed isolation device 6N137 is added between the CAN controller SJA1000 and the CAN transceiver PCA82C250, and the power supply is also isolated by a miniature DC/DC module.
4. Connecting CANH and CANL of PCA82C250 with CAN bus through a 5Ω resistor, which can limit current and protect PCA82C250 from over-current. CANH and CANL are connected in parallel with a capacitor of 30pF to ground, which can also filter the high frequency interference on the bus.
5. The damage of transmission medium or bus driver will destroy the reliable communication of CAN. If these faults can't be automatically detected and taken corresponding measures to eliminate them, the communication ability of the system will be partially or even completely lost. The effective way to solve this problem is to adopt redundant communication control, so as to ensure the normal operation of the main functions of the communication system and improve the reliability of the system.

### 4.2. System software design

#### 4.2.1. Main program design flow chart

The software of electric drive system of electric vehicle is mainly composed of main program, timer 0 interrupt service program, voltage PID control program, power PID control program, etc. It has three working modes: PWM, voltage and power, and the development environment is still CCS3.3. The main program enters the main loop after all initialization is completed. The main loop first inquires whether the CAN bus receives new information, and if it receives new information, it first processes the received information. If no new information is received or information processing is completed, the next step is to inquire whether the AD conversion program is completed, and if the conversion is completed, the AD conversion result is processed. Put the current system information (voltage, current, temperature, braking power, etc.) into
the remote frame mailbox of CAN bus. If AD conversion is not completed or information processing is finished, the next main cycle will be started. The main program flow chart of electric brake is shown in Figure 4.

**Figure 4** Main program design flow chart

### 4.2.2. Software design of CAN communication system

After the hardware platform of CAN communication network for electric vehicles is completed, it is necessary to design related software to realize CAN communication between nodes.

Except the main controller node, the software flow of each test node is basically the same, but the data frames sent and received by each node and the interpretation of the data frames are different. The software of each node mainly includes the following four parts: CAN bus data transceiver control, analog voltage acquisition, LCD control and CAN data frame analysis. The software flow of the main controller (gateway) is basically the same as that of other nodes, except that two CAN controllers need to be initialized separately during initialization.

Each node collects data by timing interruption, triggering the A/D converter every 5ms and sampling once. The receiving and sending of CAN information frames of each node is also carried out by interruption. The receiving interrupt priority of CAN information frame is higher than the timer interrupt priority to ensure timely processing of received data. The transmitted data is displayed on the microprocessor connected to LCD, PB1 is the PWM output port, PB7 is the brake signal input, and PB3, PB2 and PB0 are the input terminals of motor 3-phase Hall signal respectively. In this way, the over current sampling voltage is 1.5V. In addition, pins 9, 10 and 11 of IR2130 are configured with appropriate resistance values to make IR2130 output fault signal when the current reaches 17A.

### 4.2.3. Data frame structure

This system adopts CAN standard frame format, including 2-byte identification field and 0-8-byte data field. According to the function of this system, the uplink data (data transmitted from the lower computer to the upper computer) is sent at the request of the bus, while the downlink data (data transmitted from the upper computer to the lower computer) is sent as required, such as when the system is initialized or when there is control data to be sent. In order to ensure the reliability of data, all downlink data have their return frames, that is, the lower computer node should send a return frame to indicate confirmation after receiving the data. The uplink data is requested to be sent, so as long as the information is received, it can be judged that the node works normally. The basic structure of data frame is shown in Table 1.
Table 1 Basic structure of data frame

| Data information | Frame information | Identification number 1 | Identification number 2 | Data bytes 1-8 |
|------------------|-------------------|-------------------------|-------------------------|----------------|
|                  | FF                | ID.28                   | ID.20                   | D7             |
|                  | RTR               | ID.27                   | ID.19                   | D6             |
|                  | 0                 | ID.26                   | ID.19 (RTR)             | D5             |
|                  | 0                 | ID.25                   | 0                       | D4             |
|                  | DLC.3             | ID.24                   | 0                       | D3             |
|                  | DL                | ID.23                   | 0                       | D2             |
|                  | C.2               | ID.22                   | 0                       | D1             |
|                  | DL                | ID.21                   | 0                       | D0             |
|                  | C.1               |                          |                          |                |
|                  | DL                |                          |                          |                |
|                  | C.0               |                          |                          |                |

The frame information, FF represents the frame format, FF=1 uses the extended frame, FF=0 uses the standard frame, so here FF=0 RTR is the remote frame sending request, the remote frame is 1, and the data frame is 0. In this system, the upper computer polls the lower computer by sending the remote frame. DLC.X indicates the byte length of data. The length range of data bytes is 0-8, and the encoding form is as follows:

Number of data bytes=8×DC.3+4×DLC.2+2×DLC.1+DLC.0

The identification code of standard frame format has 11 bits. When used in bus arbitration and acceptance filter, the lower the binary value of the identification code, the higher the priority. In this system, the downlink data, that is, the control information and data sent by the upper computer, have higher transmission priority than the uplink data, so the downlink data ID.28=0 and the uplink data ID.28=1. Considering that the response frame (uplink) of the downlink command should have higher transmission priority than the ordinary uplink data, it is stipulated that the response frame ID.21=0 of the downlink command and ID. 21 = of the uplink data.

5. Conclusion

Electric vehicle is a new hot spot in automobile research and application. Compared with traditional cars, electric cars have the following advantages: zero emission and no environmental pollution. The efficiency of motor control is higher than that of internal combustion engines, which can save energy. In order to better meet the needs of car operation and create a good environment for drivers and passengers, it is very important for the development and improvement of electric drive system. This paper introduces the characteristics of CAN bus and its application in electric vehicles, designs the node setting of electric drive system of electric vehicles based on CAN bus, and introduces general expansion unit to simplify the hardware design of the system, and optimizes the design of battery management control unit which affects the performance of electric vehicles. The system has the advantages of compact structure, high reliability, perfect functions and low cost, and can better meet the working requirements of electric vehicles.

References

[1] Yang yang, ma yuqiu. Research on control strategy of intelligent charging system for electric vehicles. Electric drive, vol. 049, no. 012, pp. 64-70, 2019.
[2] Luo Jiming, Kong Wanqi, Zhang Yang, et al. Design of hybrid excitation field modulation motor for electric vehicles. Electric Transmission, vol. 049, no. 006, pp. 83-88, 2019.
[3] Zhang Ailong, Yu Zhentao, Yi Siwu, et al. Design of displacement and force servo control system of electric cylinder based on cRIO platform. Electric Transmission, vol. 49, no. 04, pp. 89-92, 2019.
[4] Hailu H N, Redda D T. Design and Fatigue Analysis of an E-Drive Transmission System of Single-Speed Gear for Electric Vehicle. International Journal of Engineering Research in Africa, 2020, 48:92-107.
[5] Anil, Madhusudhanan K, Xiaoxiang, et al. Effect of a Traffic Speed Based Cruise Control on an Electric Vehicle's Performance and an Energy Consumption Model of an Electric Vehicle. IEEE/CAA Journal of Automatica Sinica, vol.7, no. 02, pp. 75-83, 2020.
[6] Zhang C, Zhang R, Wang R, et al. Design of Torque Distribution Strategy for Four-Wheel-Independent-Drive Electric Vehicle. Automatic Control and Computer Sciences, vol. 54, no. 6, pp. 501-512, 2020.

[7] Liu Wenrui, Lin Lingyan, Tian Muqing. Study on voltage stability of charging power supply for electric vehicles based on reference model. Electric Transmission, vol.50, no. 08, pp. 48-54, 2020.

[8] Zheng Shixin. Focus on the safety performance requirements and test methods of wireless charging system for electric vehicles. Electric Drive Automation, vol. 39, no. 05, pp. 9-14, 2017.

[9] Madhusudhanan A K, Na X. Effect of a Traffic Speed based Cruise Control on an Electric Vehicles Performance and an Energy Consumption Model of an Electric Vehicle. IEEE/CAA Journal of Automatica Sinica, vol. 7, no. 2, pp. 386-394, 2020.

[10] Mao zeqiang, yang yaoquan. design of vehicle virtual instrument system based on can bus. instrumentation users, vol. 024, no. 012, pp. 19-21,96, 2017.

[11] Zhang Wenqiang, chenchen, Liu Wenjun, et al. the design and implementation of fault diagnosis system of electric vehicles based on can bus. Information and communication, vol. 006, no. 005, pp. 101-102, 2018.

[12] Li Na, Zhang Wenwen, Yue Shiyuan. Design of electric brake for electric drive system of electric drive dump truck. Mechanical Design and Manufacture, vol. 05, no.315, pp. 185-188, 2017.

[13] Zhong Hua, Chien Sun, Shen Zuying, et al. Research on electric drive system of electric vehicle. auto time, vol. 327, no. 03, pp. 56-57, 2020.