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Electric vehicle control system based on CAN bus

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Abstract. The purpose of this paper is to develop a theoretical basis for improving electric vehicle control system which based on controller area network (CAN) bus. Based on the CANOPEN protocol, electric vehicle control system was analyzed, which mainly focused on DS301and DS302 sub protocol. The method is to design a electric vehicle control system of by CANOPEN network. Then, strategy for electric vehicle control was studied and operation mode and working condition of electric vehicle was concluded. Finally, hardware and software systems of electric vehicle control system were designed. Mainly, hardware concerning flyback power supply and main controller were debugged. Modular method was adopted when designing software. Software was classified into five modules to design according to its function. The experimental results show that the electric vehicle system based on CAN bus is suitable for the development of both hardware and software. Based on the above finding, it is concluded that electric vehicle control system was improved to a certain extend.

Key words. Electric vehicle, CAN bus, control system.

1. Introduction

Transportation is more and more convenient with the rapid development of automobile industry in recent years. However, more and more environment and energy issues are emerging [1], which interferes heavily in the quality of people's lives. For example, some regions in the world are instable and global economy development is influenced because of unbalanced petroleum distribution. Besides, automobile industry account for a large proportion of the world's greenhouse gases because a large amount of fossil fuel is assumed. Moreover, vehicle emissions such as respirable suspended particulates, carbon monoxide and oxynitride would increase the incidence of respiratory disease [2–3]. For these reasons, electric vehicle is needed. Comparing with traditional vehicle, electric vehicle has many advantages, such as environmental-friendly, easy to drive, high efficiency, and low noise. There are no engine, transmission and exhaust system. Besides, electric vehicle can charge in off-peak hours of power demand, which can reduce power shortage in peak hours [4].

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Electric vehicle can be dated back to 1880s, which developed rapidly until 1920. Since 1920s, electric vehicle is gradually replaced by automobile because more and more petroleum was exploited and there are more and more studies about automobile. However, since 1950s, electric vehicle industry was attached great importance again because more attention was paid to oil crisis, environmental protection and rational used of energy [5]. Electric vehicle is a complex systematic engineering, which needs a reliable control system with superior performance to comprehensively coordinate and control the work of various components [6]. Therefore, study on design of electric vehicle control system is of great important to the development of electric vehicle technology. Many scholars at home and abroad have studied electric vehicle control system.

For example, a new controller is researched and developed [7], which can be used to reduce vibration by disturbing observer and enhance stability of power transmission system of electric vehicle using electrical machine. The control slip rate of electric vehicle with changing parameters was controlled by sliding-mode [8]. Based on Nissan LEAF blade electric vehicles (BEV), Kawamura and his partners integrated its two forward gears to set dynamic model and economic model [9]. Different driving control strategies for three models were designed based on different driving conditions [10]. The strategy for automatic mode identification is studied based on fuzzy control system. Thus, electric vehicle control system based on CAN bus was to be studied to improve control system [11].

2. Materials and methods

2.1. Application of CANOPEN protocol in electric vehicle

For those electric vehicles in use, several electronic control units are controlled by main controller through CAN bus [12], for example, electric machine, ABS/ESP unit, automotive dashboard, battery controllers, air conditioner controller, and controllers of door, window and windshield wiper. In common, electric vehicle bus is made up of two or three CAN bus. A high-speed CAN bus is used to connect main controller to electric machine driver while one or two other low-speed CAN buses are used communication between main controller and low-speed signals. Thus, for the system studied only two electric machines were controlled by main controller through CAN bus (see Fig. 1) and the other parts will be worked out in the future work.

Basic CANOPEN network is built according to DS301 sub protocol of CANOPEN protocol, which is able to distribute identifier, establish object dictionary, initialize SDO and PDO communication objects, and establish state machine and management objects of NMT network. However, with the most basic network functions, this network was unable to meet requirements of complex system. Thus, start-up procedures of CANOPEN network was designed based on DS302 sub protocol of CANOPEN protocol and electric machine control protocol stack was built based on DS402 sub protocol of CANOPEN protocol for the application of CAN bus to electric vehicle.

DS301 sub protocol defines state machine for network management and ways

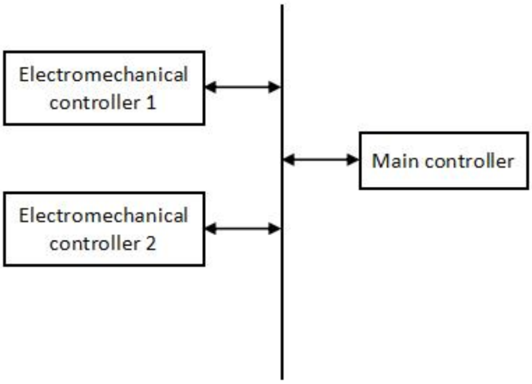

Fig. 1. CAN Bus structure of electric vehicle

to switch node network state. Simple systems such as vo module can be start-up with this procedure while complex system such as electric machine driver, should be start-up with an improved start-up procedure to ensure all nodes were started-up safely. Under CANOPEN protocol, main engine need to reset communication of sub-ordinate computer before starting up sub-ordinate computer node. State of sub-ordinate computer node should be checked by NMT main machine before sending instruction to reset communication [13] because equipment such as machine controller would enter a special working mode similar to manual mode when NMT main engine suddenly lost connection.

Figure 2 shows start-up procedure of CANOPEN network based on DS302 sub protocol. Configuration audit for software version under DS302 sub protocol was ignored because network structure of this system was simple. Currently, the system studied controlled two cooperative-working electric machine controllers whose sub-ordinate computer node was set as necessary and states need to be reviewed before start-up when configuration network.

2.2. Electric vehicle control strategy

Electric vehicle control system was made up of several components and sub-systems, including electric machine controller, energy management system (EMS), vehicle control system, accelerator pedal and brake pedal. This control system was based on vehicle control unit, which transmits and exchanges information with CAN bus. Figure 3 shows structure of the vehicle control system.

Electric vehicle has four gears, which operation can be classified into such five modes with the used of accelerator pedal and brake pedal as neutral position, normal driving pattern, braking mode, failure mode for protection and start mode [14]. After processing signals of key, pedal, gears and signals of other sensors according to control strategy, electric vehicle controller identified the corresponding model and passed the corresponding instruction into corresponding control unit to control the vehicle accordingly. According to those five models, seven working conditions can be achieved, such as parking, braking, charging, reversing, driving, starting and limb driving mode, which basically included all working conditions of electric vehicle and met the basic driving function of vehicle. Vehicle control system determines specific working conditions mainly according to key signal (Key-On), accelerate pedal signal (APP), driving gear signal (Gear-D), minimum power for vehicle normal operation (SOC-Low), reversing gear signal (Gear-R), charging request signal (Charge-Req), braking pedal signal (BPP), defective cells (Fault1, Fault2), and battery signal (SOC) [15].

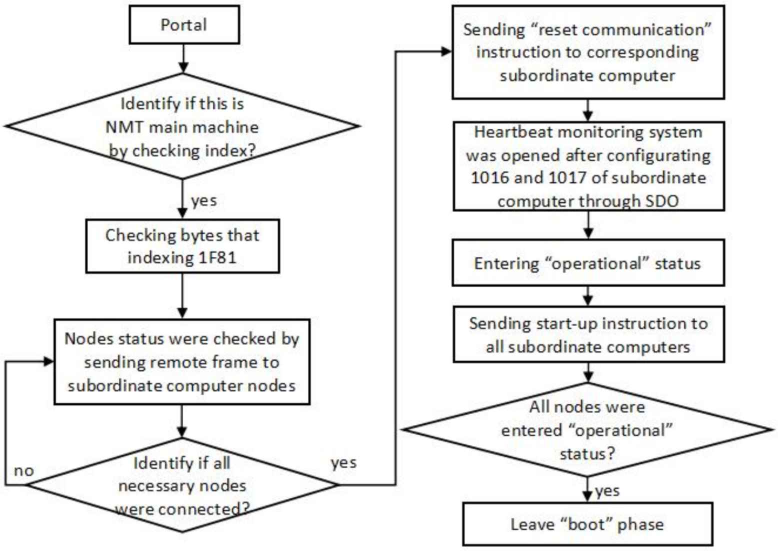

Fig. 2. Flow chart of main engine start-up procedure of the studied system

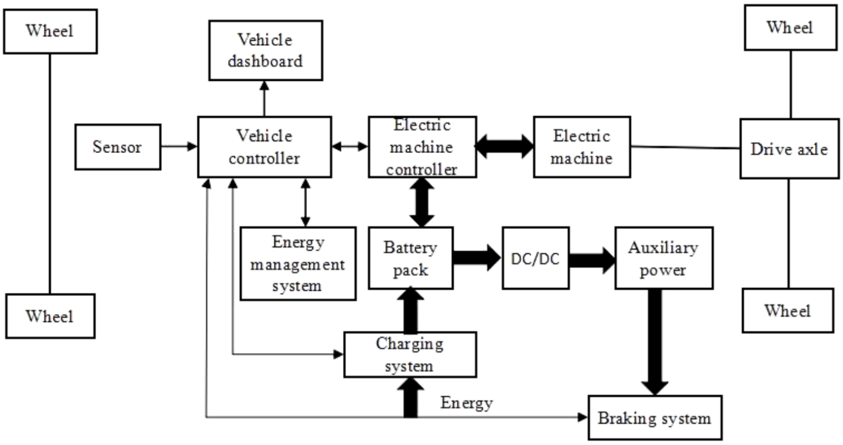

Fig. 3. Structure of electric vehicle control system (Thick arrows stands for energy flow; thin arrow stands for control signal; straight line stands for mechanical joint)

3. Experimental results and discussion

3.1. Hardware design for electric vehicle control

The electric vehicle system was powered by 72 V storage battery which was directly connected to direct current (DC) bus of electric machine. However controller chips need to be powered by low voltage of S V/3.3 V, so switch signal for MOSFET switch tube should be more than ten volts. Thus, a battery was designed to convert 72 V into SV or 12 V. In the system designed, current of 1.2 A was needed by SV and 0.6 A was needed by 12 V. Simple LDO linear chip was inappropriate for declining voltage because of large output current and great voltage differences between 72 V and 12 V. Thus, fly-back DC/DC power with high-frequency transformer was used. Figure 4 shows topological structure of fly-back DC/DC power.

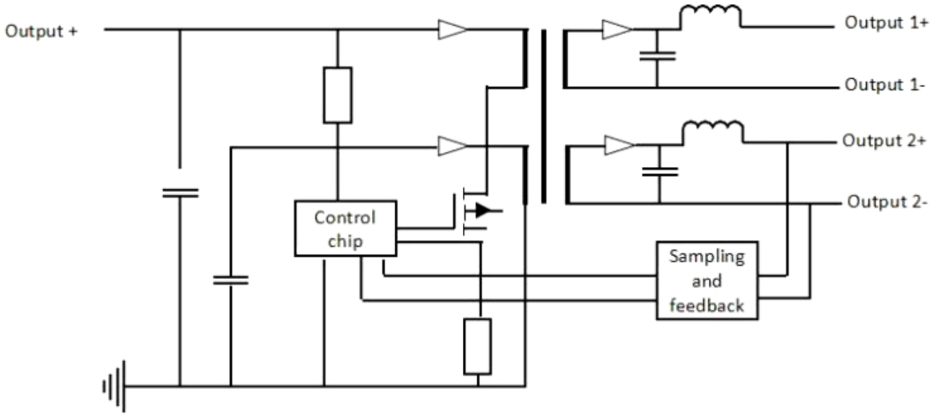

Fig. 4. Topological structure of fly-back DC/DC power

Function of high-frequency transformer was similar to power inductor which storage energy when MOS breakover and release energy to secondary side when MOS turned off. Totally, there were four parallel branches for windings. One of them was subsidiary loop output used to supply power for chip control loop. Two of them were output windings connected to load, outputting 12 V and SV voltage respectively. SV winding was designed as feedback loop because it supplied power for digital circuit which needs relatively higher accuracy.

MCU of TMS320F28035 type was used as central controller of main controller of electric vehicle. Signals listed in below Table 1 should be detected by main controller. Interface circuit for digital signal detection was simple, which can connected to GPIO interface of MCU after partial pressure followed by Π-shaped filter circuit. Vehicle speed signal, pulse signal, was connected to ECAP pin of MCU. 3.3 V power supply was used by MCU and voltage range of AD interface was 0–3.3 V. Power of common electronic pedal sensor and electronic steering sensor were supplied by SV and the range of outputted analog signal was 0–5 V. Thus, analog signal cannot be directly input in MCU. Figure 5 shows AD interface circuit. Electric machine controller was configured by main controller through CAN bus. Figure 6 shows CAN interface circuit of main controller.

Table 1. Semaphores to be detected by main controller of electric vehicle

Sigals	Signal type	Voltage range
Vehicle speed	Pulse	0–5 V
Switch	Number	0–5 V
Direction switch	Number	0–5 V
The reserved switch	Number	0–5 V
Signal of accelerator pedal	Simulation	0–5 V
Signal of brake pedal	Simulation	0–5 V
Turning signal	Simulation	0–5 V
Temperature measurement	Simulation	0–5 V

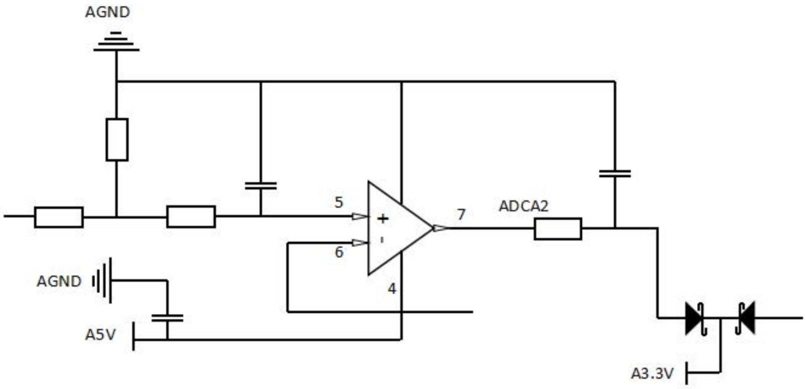

Fig. 5. Schematic diagram of AD interface circuit

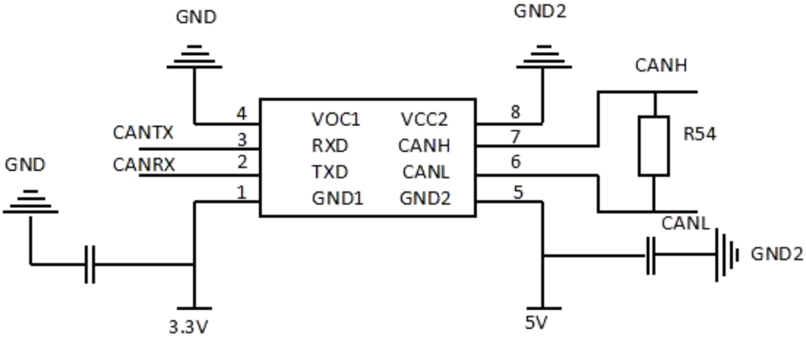

Fig. 6. Chip circuit of CAN bus interface

3.2. Software design for electric vehicle control system

Software was of great importance for vehicle controller because all parts of vehicle were controlled by software. Different modules were used to design software according to software functions. Based on different functions, software of vehicle controller was classified into such three hierarchies as management, executive and interface. Figure 7 shows hierarchy structure.

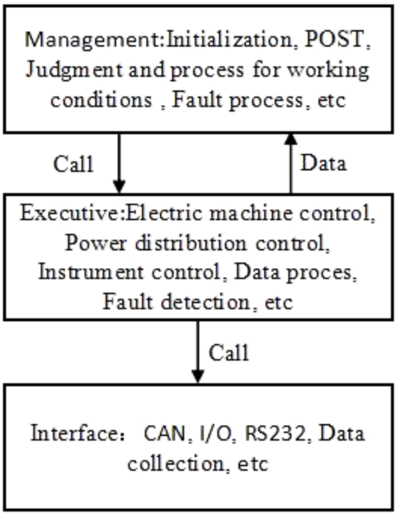

Fig. 7. Software overall structures

Main program was the key of software design, which was used to identify working status of vehicle according to collected operational information and real-time status of vehicle. Figure 8 shows flow chart of main program.

Subprogram design, power-on-self-test (POST), fault detect, failure process, and judgment and process of working conditions were tackled in subprogram design. First, all modules of controller should be initialized before operating procedures. Figure 9 shows specific modules' content and initializing sequence. POST was needed after initialization and following Fig. 10 shows POST flow chart. To ensure security, fault detection was made for all parts of system and Fig. 11 shows failure detection flow chart. If it detected failures, failure process was needed. If there are no failures, it moves to judgment and process for work condition. Vehicle working condition was determined according to collected operation information and real-time status of all parts of vehicle. Then, corresponding instructions were given to control normal operation of vehicle.

3.3. Design of electromagnetic compatibility (EMC)

Frequency converter and motor are two serious electromagnetic interference sources of electric vehicle. The frequency converter consists of two parts, the main loop and

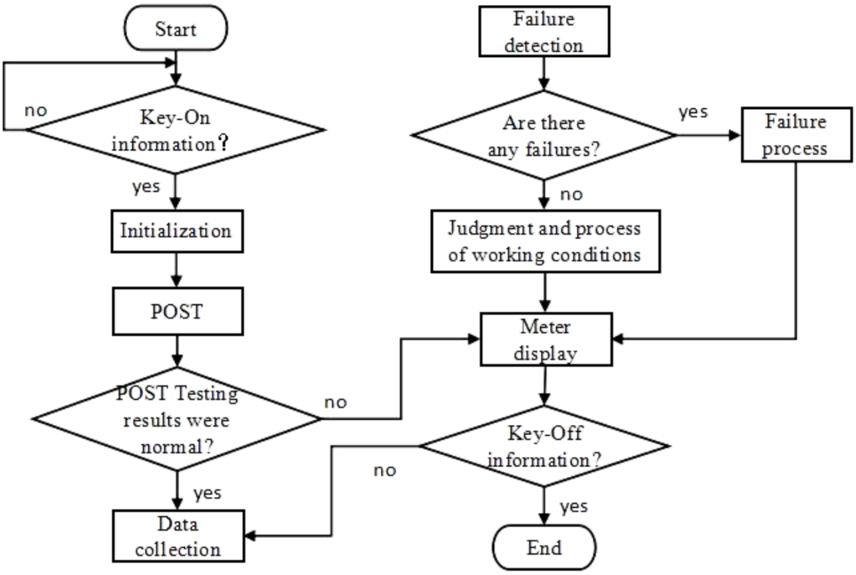

Fig. 8. Flow chart of main program

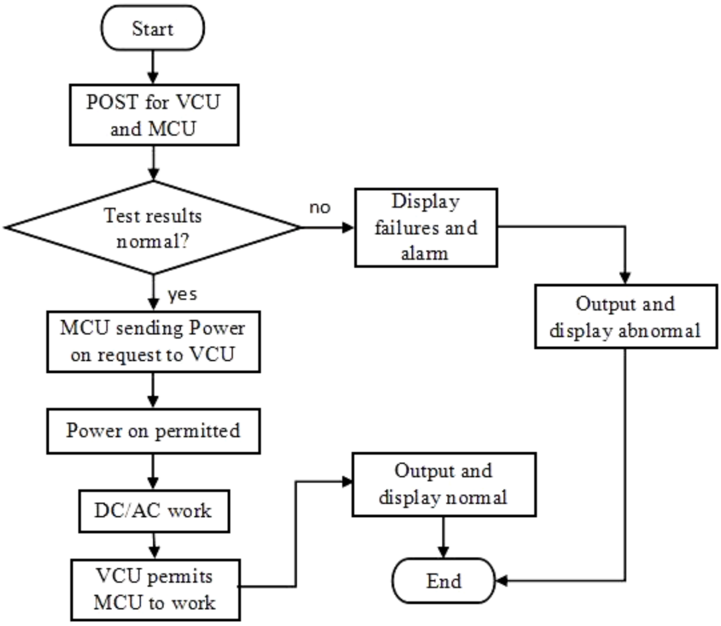

Fig. 9. Flow chart of POST

the control loop. The main circuit of frequency converter is mainly composed of rectifier circuit, inverter circuit and control circuit, in which rectifier circuit and inverter

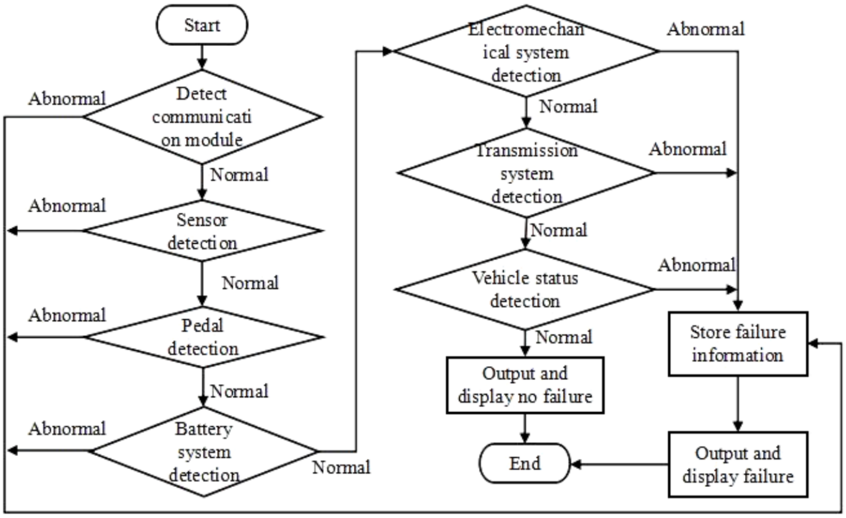

Fig. 10. Flow chart of failure detection

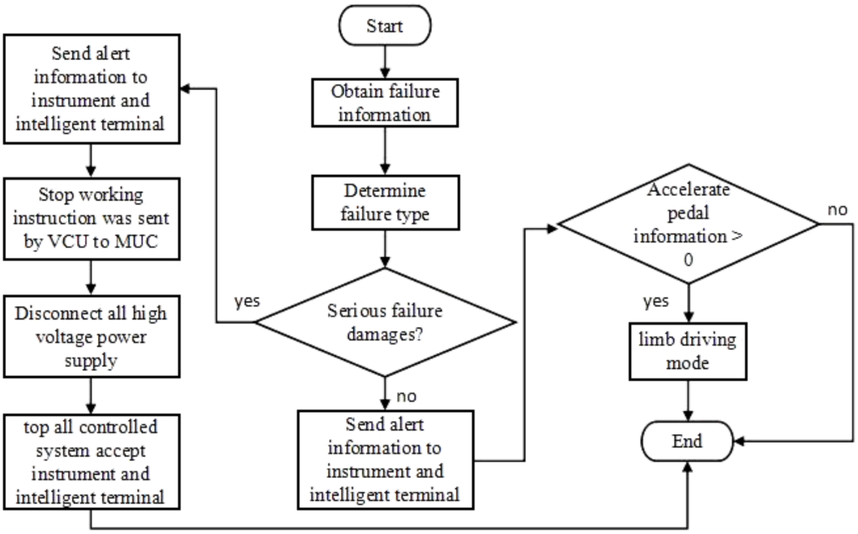

Fig. 11. Flow chart of failure processing

circuit are composed of power electronic devices. The power electronic device has nonlinear characteristics. When the inverter is running, it has to do fast switching, resulting in higher harmonics. Therefore, the output waveform of the inverter contains a large number of higher harmonics besides the fundamental wave. No matter what kind of interference, the higher harmonic is the main reason for the interference of the inverter. Therefore, the converter itself is the harmonic interference source, so it will affect the power side and the output side of the device. Higher order harmonics have strong radiation effects. If the harmonic energy is directly broken or entered into the digital equipment by other means, then it will disturb the normal operation of the equipment, increase its failure rate, and affect the service life of the equipment. The motor is an inductive device. When the motor works, it will produce strong pulse flow. At the same time, it can spread in the power network and radiate into the surrounding space. The opening, stopping and load change of the motor will change the working current and produce the pulse current, especially the rectifier motor. This interference is represented by an irregular pulse stream with a spectrum of about l0 kHz–1 GHz. Other electromagnetic interference sources include microprocessors, microcontrollers, electrostatic discharges, and instantaneous power actuators, such as electromechanical relays, switching power supplies, and lightning. In a microcontroller system, the clock circuit is usually the largest wideband noise generator, and this noise is scattered across the spectrum. With the application of a large number of high speed semiconductor devices, the edge hopping rate is very fast, and this circuit can produce harmonic interference up to 300 MHz.

All electronic circuits can receive transmission of electromagnetic interference. Although some of the electromagnetic interference can be received directly by radio frequency, most of them are received by instantaneous conduction. In digital circuits, critical signals are most susceptible to electronic interference. These signals include reset, interrupt, and control signals. The low level amplifier, the control circuit and the power supply adjustment circuit are also susceptible to noise. In order to design electromagnetic compatibility and meet electromagnetic compatibility standards, designers need to minimize radiation to enhance their susceptibility to radiation and interference immunity. Both emission and interference can be classified according to the combination of radiation and conduction. Radiation woe is very common in high frequency, but conduction path is more common in low frequency.

4. Conclusion

Vehicle control system was studied based on CAN bus. Basic structure for CAN bus was built based on DS301 sub-protocol. Then, start-up procedure of CANOPEN network for electric vehicle control system was built according to reference protocol DS302. Electric vehicle operation was classified into five modes and seven working conditions according to its four gears and use of accelerate pedal and brake pedal. Finally, hardware and software of electric vehicle control system were designed. Hardware of flyback power supply and main controller were debugged during hardware design. Modular method was adopted in software design. According to its functions, software was classified into three different hierarchies, including management, executive and interface, to be designed by different modulus. Then, main program and sub-program including initialization, POST, failure detection and process, and judgment and process of working condition were designed.

However, further study is needed because of limited research conditions, time and knowledge. It is at preliminary design phase for software and hardware design of vehicle controller. More efforts were needed in the future study to design a complete and practical controller.

References

[1] M. Sarancha: *An analysis of regional strategies and programs in the framework of the development of automobile tourism in the Central Federal District.* Universities for Tourism and Service Association Bulletin *9* (2015), No. 1, 34–41.

[2] E. Magaril, R. Magaril: *Improving the environmental and performance characteristics of vehicles by introducing the surfactant additive into gasoline.* Environmental Science & Pollution Research *23* (2016), No. 17, 17049–17057.

[3] I. J. Lu, S. J. Lin, C. Lewis: *Decomposition and decoupling effects of carbon dioxide emission from highway transportation in Taiwan, Germany, Japan and South Korea.* Energy policy *35* (2007), No. 6, 3226–3235.

[4] J. Peng, H. He, W. Liu, H. Guo: *Hierarchical control strategy for the cooperative braking system of electric vehicle.* Scientific World Journal (2015), No. 4, ID 584075.

[5] Y. Wang, L. H. Hui, B. Liu: *The study of intelligent scheduling algorithm in the vehicle ECU based on CAN bus.* Open Cybernetics & Systemics Journal *9* (2015), No. 1, 1461–1465.

[6] H. Zhao, G. F. Li, N. H. Wang, S. L. Zheng, L. J. Yu, Y. Gao: *Research status of several key technologies for the development of electric vehicles.* Applied Mechanics and Materials *160* (2012), No.Chapter 3, 361–365.

[7] J. M. Rodriguez, R. Meneses, J. Orus: *Active vibration control for electric vehicle compliant drivetrains.* Annual Conference of the IEEE Industrial Electronics Society (IECON), 10–13 November 2013, Vienna, Austria, IEEE Conference Publications (2013), 2590–2595.

[8] T. Goggia, A. Sorniotti, L. de Novellis, A. Ferrara, P. Gruber, J. Theunissen, D. Steenbeke, B. Knauder, J. Zehetner: *Integral sliding mode for the torque-vectoring control of fully electric vehicles: Theoretical design and experimental assessment.* IEEE Transactions on Vehicular Technology *64* (2015), No. 5, 1701–1715.

[9] C. Lv, J. Zhang, Y. Li, Y. Yuan: *Mode-switching-based active control of powertrain system with nonlinear backlash and flexibility for electric vehicle during regenerative deceleration.* Institution of Mechanical Engineers, Part: D, Journal of Automobile Engineering *229* (2015), No. 11, 1429–1442.

[10] Y. Chen, W. Liu, Y. Yang, W. Chen: *Online energy management of plug-in hybrid electric vehicles for prolongation of all-electric range based on dynamic programming.* Mathematical Problems in Engineering (2015), ID 368769.

[11] H. Wang, Q. Song, S. Wang, P. Zeng: *Dynamic modeling and control strategy optimization for a hybrid electric tracked vehicle.* Mathematical Problems in Engineering (2015), ID 251906.

[12] J. Wang, Q. N. Wang, P. Y. Wang, J. N. Wang, N. W. Zou: *Hybrid electric vehicle modeling accuracy verification and global optimal control algorithm research.* International Journal of Automotive Technology *16* (2015), No 3, 513–524.

[13] D. Guilbert, M. Guarisco, A. Gaillard, A. N'Diaye, A. Djerdir: *FPGA based fault-tolerant control on an interleaved DC/DC boost converter for fuel cell electric vehicle applications.* International Journal of Hydrogen Energy *40* (2015), No. 45, 15815 to 15822.

[14] C. X. Song, F. Xiao, S. X. Song, S. L. Peng, S. Q. Fan: *Stability control of 4WD electric vehicle with in-wheel motors based on integrated control of electro-mechanical braking system.* Applied Mechanics and Materials *740*, (2015), No.Chapter 3, 206–210.

[15] B. Weeks, J. Xu, B. Cao, Q. Li, Q. Yang: *Compound-type hybrid energy storage system and its mode control strategy for electric vehicles.* Journal of Power Electronics *15* (2015), No. 3, 849–859.

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