

Development of Diagnostic Equipment for ECU Parts Used in Electric Vehicles

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Abstract—Electric vehicles use lots of ECU controllers in the CAN network, the quality of ECU parts used in vehicles is closely related to safe driving. This paper develops a kind of fault diagnostic equipment for electric vehicles' ECU controllers. This device has designed digital input signal acquisition module, the output switch signal module, power supply module and fault simulation module based on CAN bus communication principle. Then we use LabVIEW developing computer program in order to monitor and control the whole system.

Keywords—Electric Vehicle; ECU; Fault diagnosis LabVIEW; CAN Bus

I. INTRODUCTION

The rapid development of Chinese economy has made car ownership in China surpassed the global average level and grow rapidly. But China is lack of oil resources, problems of over-consumption of oil resources caused by fuel vehicles, and air pollution caused by fuel vehicle emissions should not be ignored any more. In the face of enormous pressure on energy and environmental protection, clean energy vehicles, especially pure electric vehicles have become the mainstream in today's world. The electric car uses controller area (CAN bus) structure, information can be shared, wires harnessed on the car is significantly reduced, the reliability of data has been improved. CAN network of electric vehicles use a variety of electronic control units (ECU), whether ECUs could operate reliably is closely related with the safe and reliable operation of the electric vehicles. As a new energy vehicle, the detection equipment of electric vehicles remains to be the developed, and detection methods are lack of a certain standard. Not only the detection of vehicle products is not strong, but the detection of key components such as power battery has lagged behind more which is extremely detrimental to the independent development of the industry in the future. Therefore, there is a great significance in developing a kind of diagnostic equipment for Electric Vehicle ECU test.

II. ELECTRIC VEHICLE OVERALL CAN NETWORK

CAN bus is a serial data communication protocol developed by the German the BOSCH companies from the early 1980s to solve the data exchange between the control test instruments and Hyundai Motor, which is a multi-master bus communication, medium can be double twisted pair, coaxial cable or optical fiber. The communications rate can be up to 1MBPS. Pure electric vehicle mainly uses the CAN network structure, its main electronic control unit(ECU)

concludes vehicle controller unit, ABS controller unit, body controller unit, battery management system, electric air conditioning system and so on. Each ECU controller are connected to the CAN network, as shown in Figure 1.

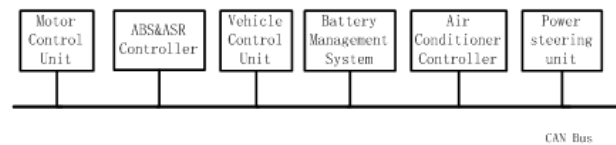


Figure1. Electric Vehicle overall CAN Network

III. HARDWARE DESIGN OF FAULT DIAGNOSTIC SYSTEM

Most of the information in pure electric car is transmitted via the CAN bus to various the controller through non-destructive arbitration mechanism to send a variety of information, including the motor speed of the motor controller sends to the CAN bus, the current size through the motor, the motor temperature, motor life signal, the total battery voltage sent by battery management system, the voltage of each battery module and so on. Diagnostic equipment developed in this article can simulate situation Car ECU works normally and the system is able to conduct fault simulation then conduct fault diagnosis of the relative ECU. The overall network of diagnostic equipment is shown in Figure 2.

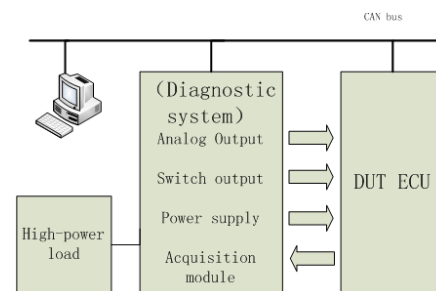


Figure2. The Overall Network of Diagnostic Equipment

This diagnostic system (the client computer) is the core of the whole diagnostic equipment, and the hardware board is the key to client computer. The hardware board of client computer consists of four functional modules: Power module, Switch module, Acquisition module, Analog module. Client computer communicate with host computer through CAN bus. The core control unit of client computer uses the NEC 78K0 FX2 series 0888 micro-processing chip. The chip has an advantage of powerful function, reliable work, simple to use, low cost, and it is widely used in electronic products of

vehicles, industrial equipment and so on. The chip supports expansion of large capacity memory. It has 50 I/O ports, 8-channel timer, multiple serial communication interfaces, including 1-channel UART (support LIN), 1 channel CSI/UART multiplexing, 1 channel CAN, 12 channel 10 bits A/D conversion channel to meet the requirement of control. The hardware design of the client computer uses CAN communication module driven by TJA1050 chip, in line with the internationally accepted the CAN communication standard ISO 11898, and design a switch acquisition circuit, an analog output circuit and self-test circuit. DAC7614 is used as digital to analog converter chip. DAC7614 is a 4 channel voltage output type chip with 12-bit precision. The maximum and minimum output voltage of each channel is set by reference voltage. The maximum output voltage is decided by the port VREFH, and the minimum output voltage is determined by VREFL. The current of analog output of this system is shown in Figure 3.

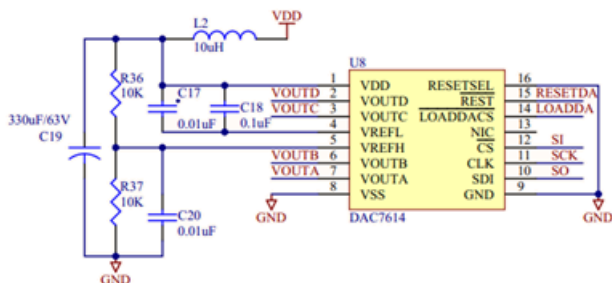


Figure3. Analog output circuit

And REST, LOADDACS, CLK, SDI are the chip's control terminals. Taking into account the principle of saving I/O ports, the development of the device's self-test function, the simplicity of system, DG406 Multiplexer chip is used to improve the integration of the device. As shown in figure 4, EN is enable terminal with active high. A0 to A3 is the control terminal, and with the combination of low and high, we could control one of the 16 channels on or off as we expect.

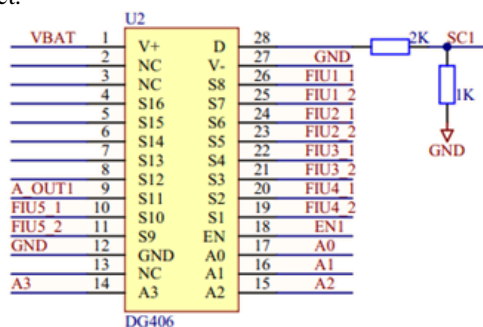


Figure4. DG406 Multiplexer chip circuit

In order to ensure that the system is safe and reliable, we finally use Max4080 chip designing a total current detection circuit as shown in figure 5.

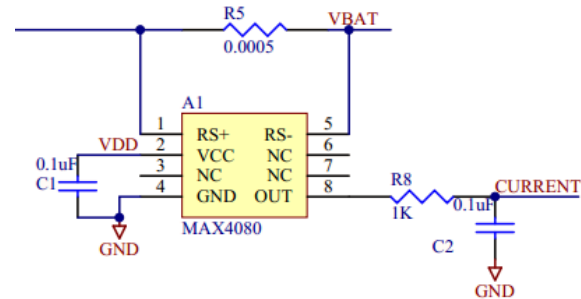


Figure5. Total current detection circuit

IV. DIAGNOSTIC METHODS AND STRATEGIES

A. Formulation of communication protocol

The host computer and the client computer should communicate through CAN protocol. Firstly we should transmit and receive handshake signal. If the handshake is successful, the host computer could send control commands to the client computer through CAN bus, then the client computer will make actions according to the control commands of the host computer. If there is data collection command, the client will collect the corresponding results then sent them to the host computer through CAN bus. Control instructions can be used to control on and off of the corresponding relay switch, control the outputs of some parameters (such as output voltage signal), control the data acquisition of the client computer (such as acquisition of switch signal, voltage signal and the current signal, and all these data need to be transmitted to the host computer). The signal of the transmission message can be divided into the switch signal and analog signal. The principle of the formulation of CAN protocol in this fault diagnostic system is listed as follows:

a) Develop the standard 11 bit CANID or 29 bit extension CANID according to the CAN protocol of the detected object.

b) ID number of control messages from the host computer to the client computer and messages from the client computer to the host computer should be distinguished clearly.

c) CAN communication speed should be consistent with the tested ECU when it works normally.

For example, the 11 bit standard ID, can develop appropriate communication protocol, control message ID from the host computer to the client computer is set at less than 0x100; message ID of the client computer sent to the host computer should be set between 0x100 to 0x1FF; Handshake request message ID sent by the host computer should be set at 0x200, the handshake response message ID from the client computer is set at more than 0x200. Take upload the analog information of the diagnostic equipment as an example, we could formulate the communication protocol as what is shown in Table 1 and table 2. The ID number is 0x112, which means the data flow is from the client computer to the host computer. Data length of code is

6 bytes, and the Table 2 defines the 4 analog signals, each is represented by 12 bits. Similarly, under the conditions that follow the protocol specification, you can formulate other message ID communication protocol.

TABLE 1 ID COMMUNICATION PROTOCOL

Returned message of current data	ID	Signal	Data stream	DL C
msgBB01_A2	0x112	sigBB01_A 2_1 to sigBB01_A 2_4	Control_board → PC	6

TABLE 2 DEFINES THE 4 ANALOG SIGNALS

Byte	Start bit	signal	Size	Note	Remark
byte 0-6	0	sigBB01_A 2_1	12	10 precision current analog	Current 5
	12	sigBB01_A 2_2	12	10 precision current analog	Current 6
	24	sigBB01_A 2_3	12	10 precision current analog	Current 7
	36	sigBB01_A 2_4	12	10 precision current analog	Current 8

B. Enactment of the diagnostic trouble code

The DTC will be built up of 4 bytes(32 bits). The upper two bytes provide the DTC code and the lower two provides further information on the failure type and DTC status. The DTC format is shown in Table 3.

TABLE 3 THE DTC FORMAT

DTC_MSB	DTC_LSB	Failure Type	Status Byte
1 byte	1 byte	1 byte	1 byte

Specifically, a complete DTC code is composed by 4 separate fields: 19 bit Suspect Parameter Number(SPN), 5 bit Failure Mode Identifier(FMI), 7 bit Occurrence Count(OC) and 1 bit SPN Conversion Method(CM). DTC can be the basis of mutual recognition of each subsystem ECU fault diagnostic tools and maintenance personnel when there occurs any faults. By analysis of the possible failure of each ECU controller, for example, CAN communication failure, we can formulate the following DTC code as shown in Table 4.

TABLE 4 THE FOLLOWING DTC CODE

Function	Sub function	DTC	DTC Code	Failure Type Byte	Description
Communication	HS CAN	Bus off	U0001	00	High speed CAN in bus off state
		Init Error	U1001	04	CAN module initialized HS CAN
		VCU Node Missing	U0100	87/E	Lost Communication With VCU Module
		ABS Node Missing	U0121	87/E	Lost Communication With VCU

					Module
		BMS Node Missing	U0155	87/E	Lost Communication With VCU Module

C. Process of diagnostic service

Firstly, we need to define physically request ID, physically response ID and functional request ID. Take Body Control Module(BCM) as an example, we can set physically request ID at 7C1, physically response ID at 7C9 and functional request ID at 7DF. Electric vehicle applies ECU module with CAN bus, and realizes the diagnostic function through communication by CAN bus. So this requires OEMs to develop, publish specification document of diagnostic requirements, clearly defined fault codes DTC (Diagnostic Trouble Code), configure the Data Address DID (Data Identifier), Diagnostic Services SID (Service Identifier). Some of the SID supported by ECU is listed in Table 5.

TABLE 5 ECU

DIAGNOSTIC SERVICE (SERVICE NAME)	SID	DEFAULT		EXTENDED	
		PHYS	FUNC T	PHYS	FUNC T
Diagnostic Session Control	10	S	S	S	S
Security Access	27			S	
Communication Control	28			S	S
Control DTC Setting	85		S	S	S
Read Memory By Address	23				
Write Data By Identifier	2E			S	
Clear DTC	14	S	S	S	S
Read DTC	19	S	S	S	S

S: Support

V. PC SOFTWARE DESIGN

PC software uses the Labview graphical programming software developed by National Instruments (NI) and it has the advantage of short development cycle and good human-computer interaction. When system is in the monitoring process, we use the KVASER USBCAN developed by the Swedish company to collect the information from the lower machine and the ECU to be tested and pass the information to the host computer. The host computer can extract the fault code from the information. After the processing of the host computer, the cause of the fault can be displayed. And the host computer can send commands through the CAN Bus to the lower machine and the ECU to be tested, and command them to complete the diagnostic instruction. This paper uses the KVASER built-in Labview program module

to read and write the information through the CAN Bus. The program diagram about reading the CAN Bus information is listed in Figure 6.

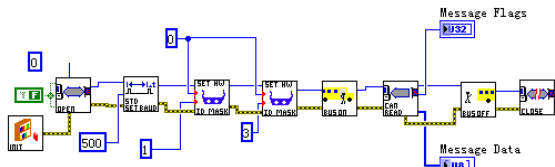


Figure6. Program diagram about reading the CAN Bus information

The program diagram about writing the CAN Bus information is listed in Figure 7.

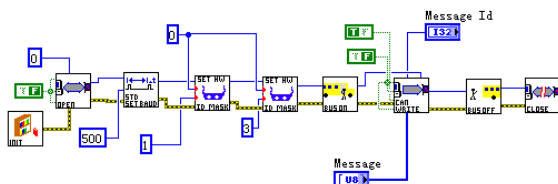


Figure7. Program diagram about writing the CAN Bus information

The process diagram of the whole diagnosis is shown in Figure 8 as follows.

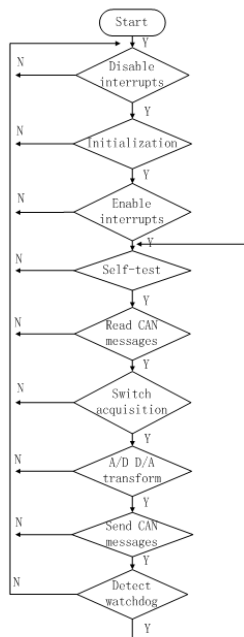


Figure8. Process diagram of diagnosis

The Figure below shows the program interface in running, and Figure 9 is for the vehicle controller interface (main motor failure), and it plays an important role in the actual testing of vehicles.



Figure9. Vehicle controller interface

VI. SUMMARY

This paper developed CAN Bus fault diagnostic communication protocols according to the ISO 15765 International standard. After that we use the communication equipment KVASER USBCAN and the powerful Labview software to develop the fault diagnostic platform for the ECU component of the electric vehicle. The fault diagnostic platform can achieve the communication between the host computer and the client computer. The experiment shows that the system can locate the fault fast according to the fault code, and the real-time and reliability has been validated. In that sense, this system has great significance.

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