Research on Motor Diagnosis in Autocar Electronic Parking Brake System (EPB)

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Keywords: EPB, Motor, Inversion, Block, Fault code.

Abstract. When autocar electronic parking brake system (EPB) running, judging whether the motor is working properly is an important process to guarantee the system’s operation. This paper does comprehensive logical judgment on changing parameters resulted from motor’s forward, reverse and blocking to make the system works safely and efficiently. What more, it shows the fault code’s backup and extraction for troubleshooting, trouble analysis as well as system improvement.

Introduction

It is obvious that China has leapt to be the largest automobile production and marketing country by now, and automobile has entered the common people's home there. With the raising requirement on comfort, safety and intelligence for automobile, the application of electronic technology has almost penetrated into all the automobile system, and shows a tendency to spread from high-end ones to medium and low-end ones.

The automobile electronic parking brake system (EPB), as one of the key components of automobile, has been used maturely in high-end vehicles such as BMW, Mercedes Benz and Audi since the end of last century, and the related technology has been monopolized by several foreign suppliers. By contrast, this technology is started later in China, but it shows a bright future.

As an important process in product application, system diagnosis and analysis is developed rapidly with the development of computer technology and electronic technology. The commonly used non-dismantling detection is widely applied with its convenient and fast hand-held diagnostic instrument. The principle is collecting the parameters of the motor under positive, reverse, blocking and other conditions to determine whether there exists fault in it. More details about the contents of diagnosis will be shown later.

Fault Diagnosis Circuit Design

Design of Voltage Detecting Circuit for Vehicle Battery

Overvoltage will burn out the electrical appliances, switches and system lines, even the circuit board; Undervoltage will lead the switching power chip and the electrical appliance can not work properly as well as reduce the life of electrical appliance, in this sense, the detection of vehicle battery voltage is necessary.

The voltage detection circuit is designed by using the resistance divider method, the resistance signal obtained by the voltage divider is inputted to the microcontroller pin, and the voltage value of the input pin is detected by the A/D function module to calculate the voltage value of the battery and determine whether the battery voltage is normal by the way.
The voltage detection circuit is shown in Figure 1. After the voltage of the battery being divided by R13 and R20, the voltage on the R20 resistor passes through the RC filter and the voltage regulator tube D5, and then enters the A/D sampling pin of the singlechip. For the 24V battery voltage, the R13 and R20 resistance values are 20K and 3.9K, respectively; For the 12V battery voltage, the R13 and R20 resistance values are 20K and 10K, respectively. R16 aims at protecting the microcontroller pin and preventing the input pin current fluctuations to burn out the pin.

The on-board battery voltage of the DC motor type electronic parking system is DC12V, with repeated tests, under normal circumstances, the input voltage of the single chip input pin is 3.9V.

**Design of Detecting Circuit for Fault Warning Lamp**

When the system is out of order or faces malfunction, the alarm light or buzzer will flash or alarm to prompt the driver to notice the system problem. The fault lamp plays a very important warning role in the fault diagnosis. Therefore, whether the malfunction lamp is normal has a great effect on the system. The detection circuit of the fault warning lamp is shown in Figure 2.

As shown in the figure, the system judges whether the fault lamp works properly by detecting the voltage value of the 1K resistor which is in series with the faulty lamp.

**Actuator Operating Loop Current Detection Circuit**

The working state of the DC motor and solenoid valve directly affects the reliability and safety of the system. A loop current detecting circuit is added to confirm whether the actuator is in normal working state. The motor loop current detection circuit of the direct current motor system is shown in Figure 3.

Chip BTS443P has the function of fault diagnosis, which can feedback the load current value of the device. The relationship between the feedback current of the chip and the load current is shown in Figure 4. In order to increase the measurement range of the chip, the two BTS443P chips are connected in parallel so that the effective range will reach 40A. The output current of chip pin 4 is the feedback current, it will flow through the 1K resistance R10, and the microcontroller can sample the
voltage value through the A/D module, then obtain the feedback current value, and finally calculate the motor loop current value.

![Figure 4. Relation diagram between feedback current and load current.](image)

**Fault Diagnosis Communication Circuit**

The communication protocol between the electronic control unit and the fault handheld device adopts the K line protocol, so the system selects the chip L9637 which is suitable for K line communication. Features of L9637 chip: Operating voltage range, reversing voltage protection, low current standby mode and low static current, the TX input pin is compatible with the TTL input, the K line output current limit, low EMI, and EMI robustness optimization. SCM send and receive messages with chip L9637 through the UART serial communication function module. The schematic diagram of the fault diagnosis communication circuit is shown in Figure 5.

![Figure 5. Fault diagnosis communication circuit.](image)

**Software Diagnosis Strategies for Fault Diagnosis System**

**Analysis of Fault Points and Fault Phenomena**

In view of the DC motor type electronic parking brake system, the common faults, the causes of typical faults and the fault phenomena are analyzed. According to the principle of "simple to complex, easy to difficult", the fault position of the electronic control unit ECU is analyzed, and some common faults and the corresponding fault phenomena are determined. The DC motor type electronic parking brake system failure phenomenon is shown in Table 1 [3-6].

<table>
<thead>
<tr>
<th>fault location</th>
<th>Fault Phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor fault: motor loop failure or relay open circuit failure</td>
<td>Motor operation time is abnormal; no speed signal; the brake force sensor perception signal no change; the feedback current is zero</td>
</tr>
<tr>
<td>Power voltage overvoltage</td>
<td>A/D the sampling voltage is out of range</td>
</tr>
<tr>
<td>Power voltage undervoltage</td>
<td>A/D the sampling voltage is out of range</td>
</tr>
<tr>
<td>Motor rotation blockage failure</td>
<td>No speed signal (rotation blockage blocking and excessive current); Motor short circuit produces high current</td>
</tr>
<tr>
<td>EPB warning light failure</td>
<td>The feedback voltage signal is not normal when driving, and the lamp is not lighted when the component is detected</td>
</tr>
<tr>
<td>ECU diagnostic communication failure</td>
<td>The initialized ECU response code for diagnostic communication is incorrect</td>
</tr>
</tbody>
</table>

According to the fault location and failure phenomenon, the software can accurately and quickly judge the fault of the system according to the corresponding diagnosis strategy. Connect the fault diagnosis instrument, and then extract the system stored fault code. According to the troubleshooting instructions, the maintenance personnel can accurately obtain the fault and troubleshoot it.
Fault Code Table

Based on above fault point analysis, the fault code table shown as following is developed to help read the fault code to realize the communication between the electronic parking system electronic control unit and the fault diagnosis instrument. According to different faults, different levels are set so that the system can make different operations when faces failure. The fault code is shown in Table 2.

Table 2. Fault code table

<table>
<thead>
<tr>
<th>Fault Code (Code Decimal Value)</th>
<th>Fault Variable Name</th>
<th>Fault Code Description</th>
<th>Failure Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTC_1(20)</td>
<td>Motor_error_code</td>
<td>Motor loop failure or relay open circuit failure, motor operation time is abnormal</td>
<td>Level 1</td>
</tr>
<tr>
<td>DTC_4(23)</td>
<td>Voltage_high_error_code</td>
<td>Power voltage overvoltage</td>
<td>Level 1</td>
</tr>
<tr>
<td>DTC_5(24)</td>
<td>Voltage_low_error_code</td>
<td>Power voltage undervoltage</td>
<td>Level 1</td>
</tr>
<tr>
<td>DTC_7(26)</td>
<td>Motor_jam_error_code</td>
<td>Motor rotation blockage failure</td>
<td>Level 1</td>
</tr>
<tr>
<td>DTC_19(34)</td>
<td>EPB_WaringLight_error_code</td>
<td>EPB warning light failure</td>
<td>Level 1</td>
</tr>
<tr>
<td>DTC_26(45)</td>
<td>Diagnostic_CM_error_code</td>
<td>ECU diagnostic communication failure</td>
<td>Level 3</td>
</tr>
</tbody>
</table>

Remarks: In level 1 fault, the system can no longer run, the car is not allowed to operate, the fault light flashes, and the buzzer sounds alarm; In level 3 fault, the trouble alarm light is always on, but the system can run and need to be repaired as soon as possible.

Diagnostic Strategies for Motor Drive Circuit

The motor drive circuit fault may be due to the battery voltage undervoltage, lead joint loose, control drive circuit fault, motor short circuit and so on. Once the motor fails, the system will not work properly, at this time, we need to read the fault code and analyze the cause of the failure.

In order to accurately and quickly determine whether the motor is working properly, based on the analysis of the drive circuit and the above fault phenomena, the final determination is determined by viewing the feedback motor loop current value. According to the value of the feedback current, the current value of the motor circuit can be calculated to determine whether the motor line fault or the motor is blocked.

Communication Protocol

In the communication diagnosis service, the system uses K line communication protocol KWP2000 to realize communication service and fault diagnosis service. KWP2000 (i.e., Keyword Protocol 2000) is the job name of the ISO standard ISO-14230. All information protocols working on the bus are defined by the keyword, which is returned to the diagnostic communication device during the diagnostic communication initialization process. KWP2000 is compatible with ISO9141-2. By adding new options, its flexibility and ability are improved. The protocol implements a complete on-board diagnostic service, which has good communication reliability as well as low cost, and has developed rapidly in recent years.

The KWP2000 protocol based on K line mainly includes ISO14230-1~14230-3. The protocol consists of three parts: Physical layer, data link layer and application layer. The first part is defined as the physical layer, which is actually the physical layer defined in ISO9141-2, but can be extended to
work in the 24V system. This means that for any vehicle, module or test equipment that meeting the ISO9141-2, only need to modify its software, it will be able to meet the KWP2000 interface requirements. The second part is defined as the data link layer, which includes information format and timing. They are compatible with ISO9141-2, but also provide additional options, including whether the head has the address information and length information. The information can be up to 255 bytes long. In addition, the communication initialization method is defined. The third part is defined as application layer and defines the implementation method of diagnostic service[7].

Based on the analysis of the communication initialization of the k-line communication protocol and the provided diagnosis service function, to realize the communication service program of fault diagnosis, the communication module can be initialized first, and then the communication connection is established. Following this, the diagnostic instrument and the electronic control unit perform diagnostic function services.

Fault diagnosis instrument has four major functions: the fault reading, the fault code clearing, the data stream reading, and the component detection. The interface is DB-9 serial port connector. Each service corresponds to a set of service request command and positive response command words. The negative response command word is 7FH. The electronic control unit sends and receives the message frame through the UART serial port interrupt, and extracts the command word in the data frame to determine the response command word as well as the response message frame content.

The fault diagnosis device has the function of reading data stream and communicates with the electronic control unit. It can obtain the status information of the vehicle in time. When the electronic control unit receives a read data stream request, it will respond to the request and send every 8 bytes to the diagnostic device. The send and receive data definitions are shown in Table 3.

Table 3. Definition of data stream.

<table>
<thead>
<tr>
<th>Data Name</th>
<th>The Location of the Data in the Packet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Start Flag</td>
<td>DATA(0)_2</td>
</tr>
<tr>
<td>Motor Positive and Reverse Flag</td>
<td>DATA(0)_1</td>
</tr>
<tr>
<td>Motor Speed</td>
<td>DATA(4)&amp; DATA(5)</td>
</tr>
</tbody>
</table>

Remarks: DATA (0) refers to the first 8 bit data 0; DATA (0) _1 refers to the first bit in data byte 0; DATA (4) & DATA (5) refers to data byte 4 and data byte 5.

Fault Diagnosis and Debugging

After completing the system hardware design and software design, the electronic parking system and the fault diagnosis system have entered the experimental bench debugging to carry out system verification and do experimental results data analysis. Fault debugging is done by artificially manufacturing the fault point to improve the imperfectness of the fault diagnosis hardware and software diagnostic strategies.

After the quick initialization of the fault diagnosis instrument and the electronic parking brake system, it enters the interface of four functions, that is, the fault code reading, the fault code clearing, data stream reading and component detection.

Fault point diagnosis diagnoses the hardware circuit and verifies the software diagnostic strategy with the artificial setting fault. After the fault point can be determined in time and accurately, perform a data communication test with a fault diagnosis handheld device to read the fault code.
When the fault diagnosis instrument and the electronic control unit are used to read the traffic information data flow in function test. Determine whether the data flow is correct by comparing the data of the diagnostic interface with the test interface data.

After the diagnostic instrument and the electronic parking system reading the fault codes, read the data stream, detect the components, and then clear the existing or stored fault codes.

At present, the fault diagnosis system only detects the alarm lamp, the buzzer and the motor. After the detection, the diagnostic instrument shows that "The test is finished". When enters the component detection function, the electronic parking brake system receives the component detection command word 0x1B, then extracts the latter byte to determine which component is detected, and finally enters the component test subroutine of the electronic parking brake system. If the byte is 0xB0, the warning light flashes; If the byte is 0xAE, the buzzer tweets intermittently; If the byte is 0xAF, the motor will rotate intermittently. The above test phenomena can be observed or heard by tester.

Summary
Through the motor diagnosis circuit design, the fault diagnosis system software diagnostic strategy development, the motor drive circuit diagnosis strategy development, the communication protocol, and the fault diagnosis and verification, it is fully equipped with backup, reading and clearing of the fault code function, and provides an application platform for the professional and technical personnel to determine the fault, analyze the cause, solve the problem, improve the system.

Through real vehicle matching test, the technology fully meets the overall performance requirements of the autocar electronic parking brake system (EPB), and can be popularized in similar fields.

References