EVS24
Stavanger, Norway, May 13-16, 2009

Development of Battery Management System integrating OBD-II function for EVs

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Abstract

As a crucial part of EVs, BMS (battery management system) should increase its self-diagnostic function to meet higher safety requirements. On the other hand, OBD-II (On-Board Diagnostics-II) has been adopted by most of auto makers for its good capability and standardization. This paper presents a new battery system combined with OBD-II and BMS, which greatly increases the system safety and reliability. The hardware and software are developed, and the protocols for diagnosis and communication are proposed. Experiments with battery packs show that the new system achieves its design goals.

Keywords: BMS, OBD-II, self- diagnosis, diagnostic management.

1 Introduction

Battery management system (BMS), which ensures the safe and efficient use of traction batteries, plays an important role in EVs [1]. Lots of BMS have been developed during recent years, and some of them have been used in product EVs. Nevertheless, as higher safety requirements draws more and more attention, functions of self-diagnose and battery protection need to improve. Problems would happen when the battery voltage circuit fails and thus BMS get a wrong voltage signal without awareness. BMS would indicates the driver a battery is in an abnormal state and needs to take some actions like balancing or replacing the battery, and this would decrease the system efficiency and cause the driver wasting time to check the healthy batteries. This kind of erroneous judgment sometimes may cause extremely dangerous incidence as some important components or circuits fail to work when the vehicle is driving. Therefore, BMS should increase its self-diagnose ability and safe guard function to protect the battery packs as well as vehicles from malfunctions and the consequential effects.

In the past twenty years, On-Board Diagnostics-II (OBD-II) has been adopted by more and more auto makers in the world [2]. OBD provides vehicle the self-diagnostic and reporting capability, and gives the driver or the repair technician the state of health information for kinds of sub-systems. Modern OBD systems provide a standardized communication port to send data and a series of diagnostic trouble codes (DTCs), which can help the machinist rapidly identify and remedy malfunctions of the systems. Successful application of OBD-II in Engine management system (EMS) gives a good example for other related system designing.

Therefore, a BMS adopting OBD-II is developed to enhance the system and vehicle reliability. This paper will introduce development of OBD-II function in BMS and implementation of hardware/software. Finally, system test will be done to evaluate effects and performance of the system.

2 System analysis and OBD-II function design

2.1 System analysis

To integrate the OBD-II functions into a BMS, we could first make a comparison between these two systems.

Table 1: Comparison of BMS and OBD-II

	BMS	OBD-II
Function	Data acquisition, Safeguard for batteries, Thermal management, SOC calculation;	Data acquisition, System self-test, Emission monitoring;
How to deal with fault	Display for drivers, Fault storage, VCU communication, Switch off in case of emergency;	MIL(malfunction indicator lamp), DTCs storage;
Communication	CAN, TTCAN;	KWP, PWM, CAN;
Others		External tools

Through the comparison, functions and characteristics of the BMS with OBD-II can be demonstrated as the following figure:

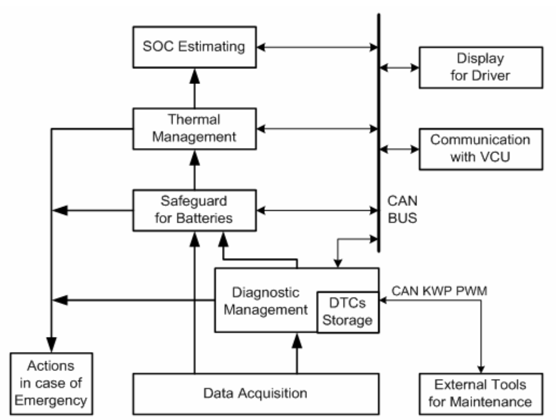


Figure 1: Function structure of the BMS

2.2 Failure modes and effects analysis of battery system

To implement OBD functions, we should first figure out potential failure modes and effects analysis of the battery system to find out what kind of failure may happen and evaluate severity of the failure. Faults can be divided into 3 sorts: component faults, controlling unit faults and battery faults. Components including sensors, actuators and some electronic/mechanic units of the system are the main part that OBD-II focuses on. Controlling unit is the most crucial part for its importance to system operation. Batteries may be in abnormal/unhealthy status when charging or discharging improperly. Different failures may cause different consequences according to their effects, so faults are evaluated by severity ranks as showed below:

Table 2. Severity of Effects

Rank	Severity (S)	
	Effect	Criteria: Severity of Effects
5	Hazardous without warning	Vehicle/system in a severely dangerous state without warning.
4	Hazardous with warning	Vehicle/system in a severely dangerous state with warning.
3	High	System/component inoperable (loss of primary function).
2	Moderate	Life/health of Batteries damaged.
1	Low	System/component operable but at a reduced level of performance.
0	None	No discernible effect.

2.3 Implementation of OBD function

After analyzing of system faults, OBD-II function can be designed. It should satisfy underlying demands.

- Signals check
- Faults identification
- Diagnosis management
- DTC storage
- Standard communication
- Emergency handling

Therefore, a diagnosis management system (DMS) in BMS is implemented to reach the target. The DMS consists of 3 function units: diagnostic check, diagnostic management and diagnostic disposal.

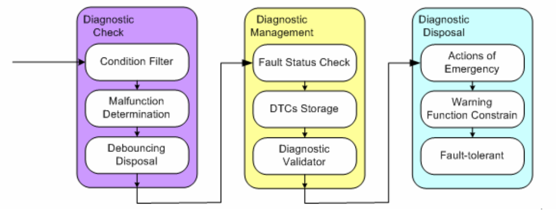


Fig. 2. Function structure of the DMS

When signal acquisition is done in a system period, the DMS will judge if the signal should be checked in case of some faults existing with higher priority. For example, if a cell voltage has been diagnosed as "too high" and the fault exists already, then there's no need to check if the cell voltage is "reasonable". That's the "condition filter". Then there must be some criterion to determine whether a signal is "healthy" or "abnormal". When an error occurs, it's not determined as a fault immediately. We use the "X/Y/T" method to distinguish a fault from a bouncing signal.

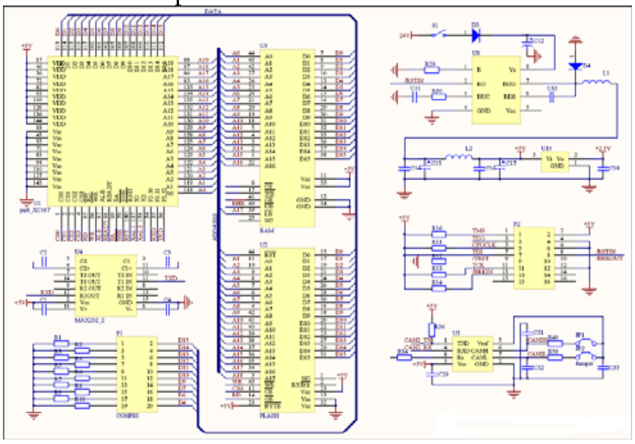
After this, a fault generated by DMS enters diagnostic management unit. Fault status check will compare the new fault status with history records, and updating DTC storage if specific difference is found. Diagnostic validator is used to check the fault is "master fault" or "slave fault". A "slave fault" means it's caused by other fault. External diagnostic tools will only respond those "master faults" stored in memory.

Diagnostic disposal takes 3 steps to handle a fault. If a fault that may lead to serious consequence is detected, related emergency handling action must be carried out, such as shutting down main contactor when batteries run into extremely dangerous situation like crash. The driver should be warned when a fault is generated and stored, and functions related should be constrained. Fault-tolerant function allows system/vehicle works at a reduced level of performance for some time until repaired.

ISO/15031: "Communication between vehicle and external equipment for emissions-related diagnostics" has defined DTCs in part 6: "Diagnostic trouble code definitions" [3]. Nevertheless, many of faults in BMS don't have a defined DTC in the standard, so DTCs of the system should be made. We use the "P10xx" segment which is reserved for manufactures.

3 Hardware design

Figure 3 shows the schematic figure of the hardware design. We choose XC167 as MCU of BMS for its good performance and abundant peripherals [4][5]. External large storage devices will be acquired because diagnostic function needs numerous program and data storage space. Figure 4 and 5 show specific circuits for signal conditioning and connector interlock check. We use a second-order low-pass filter to treat input signals so that noise mixed in original signal could be reduced. The interlock check circuit will light the LED up and output "0" to MCU to indicate that the connection passes the check.



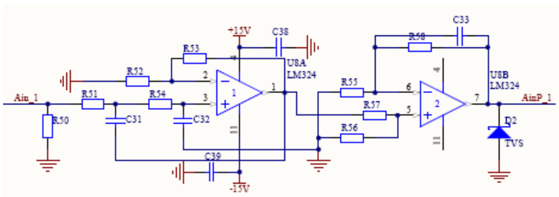


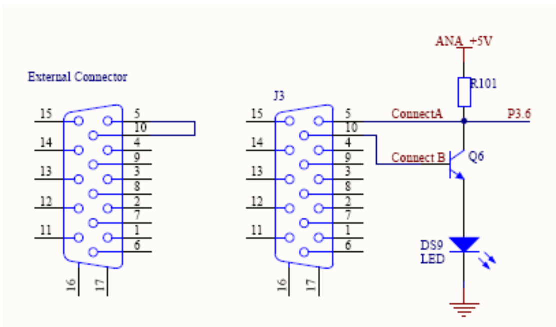
Fig.3. Part of hardware schematic layout

Fig.4. Signal conditioning circuit

Fig. 5. Connector interlock check circuit

4 Software design

The tasks of BMS will be leveled according to their importance, and the operation of BMS is set



into four modes. Program flowchart is shown as below:

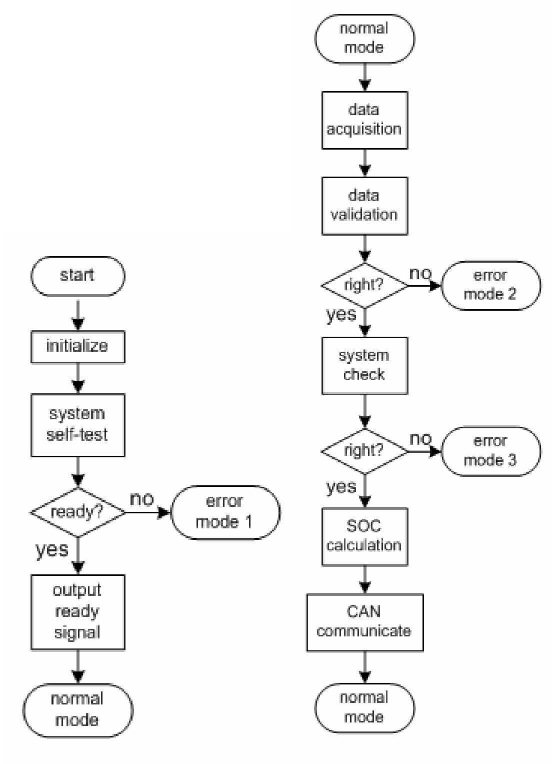


Figure 6: Flowchart of program, part 1

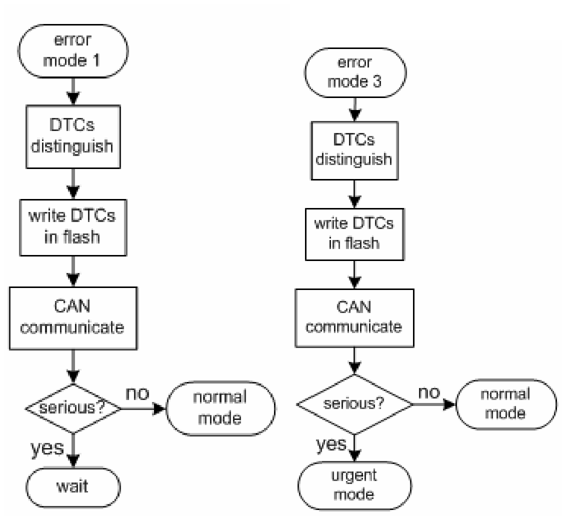


Figure 7: Flowchart of program, part 2

5 System test

Circuit board of BMS is achieved and tested with 10 battery cells. At the normal condition, regular functions of BMS such as voltage acquisition, temperature acquisition and SOC estimating are realized. The OBD function is checked with an external diagnostic simulator, which can simulate different faults of sensors and actuators. During the test, kinds of faults were generated, and the results can be observed through the LED in the circuit board. And DTCs stored in Flash memory can be read through CAN bus. Test result shows that self-diagnostic function of BMS is realized and stability of the whole system gets enhanced.

6 Conclusion and future work

A BMS integrating OBD-II is developed, and experiment results show that the exercise of the system has good capability and stability.

Standardized communication is another part of OBD-II designing. Interface between BMS and external diagnostic tools will be designed and protocol of communication is also need to be accomplished.

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