BMS

Part 01

Developing Technologies for Battery Management

Switch-Failure Diagnosis in a 12-Volt Battery

Battery management systems (BMS) are becoming crucial for building stable, battery-based power sources for automobiles and industrial systems. A BMS estimates the battery status, and controls the switching on a charge-discharge path. Smart battery management enhances battery performance and improves the reliability of the products that integrate them. This series highlights some aspects of our development of this technology.

A BMS is made up of switches, e.g., relays, or field-effect transistors (FET), measurement components, and a control unit. To protect the battery from over-charging or over-discharging, the BMS operates the switches before the host battery comes to an abnormal state. Therefore, the BMS should perform a switch-failure diagnosis self-test at appropriate times to confirm the readiness of the switches to operate correctly when they receive a signal.

Through the following examples, this article explores technical concepts surrounding switch-failure diagnosis, which we developed for application to the 12V battery.

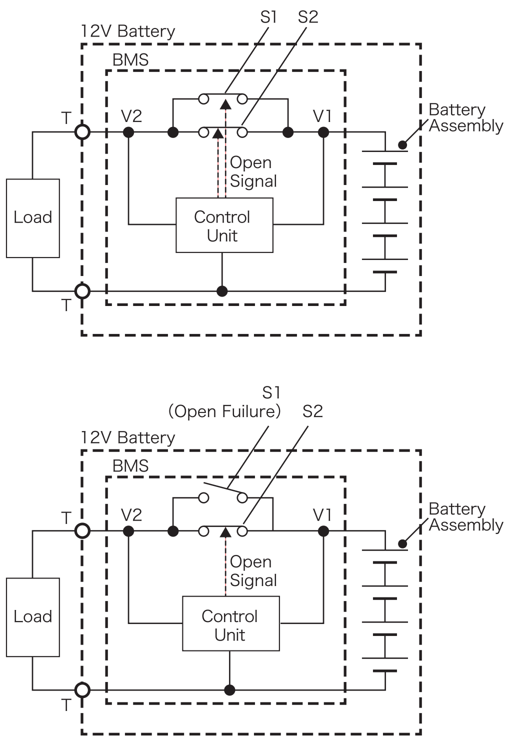
Switch-Failure Diagnosis with Parallel-Connected Switches

Consider a 12V battery built into a housing together with a battery assembly, configured from, for example, four series-connected Li-ion cells, and a BMS[1]. During normal operation of the 12V battery, the battery assembly charges when all the switches —which are connected in parallel on the charge-discharge path between the battery assembly and an external terminal T— are closed (top, ●Fig. 1). To protect the battery when, for example, over-charging or over-discharging is detected, the BMS opens all the switches simultaneously to block charging or discharging.

Switch-failure diagnosis can be performed without interrupting the power supply to the load by testing for fail open (i.e., switch does not close) and then fail closed (i.e., switch does not open). Specifically, before supplying power to the load, the BMS measures load voltage V2 while signaling the switches alternately to open. If switch S1 fails open, then the charge-discharge circuit path is blocked when the BMS signals switch S2 to open (bottom, ●Fig. 1). At this time, the BMS determines that switch S1 is failed open by detecting the decrease in load voltage V2.

After that, as power is being supplied to the load, the BMS signals each switch alternately to open while measuring the difference between battery-assembly voltage V1 and load voltage V2, thereby measuring the voltage drop across the switch terminals. If switch S2 failed closed (top, ●Fig. 1), both switches remain closed even when the BMS signals switch S2 to open. Consequently, the voltage drop across the switch terminals would be small compared with when one of the switches is open. Here, the BMS can determine that switch S2 failed closed by detecting that the voltage drop across the switch terminals is small[2].

●Fig. 1 Switch-Failure Diagnosis with Parallel-Connected Switches

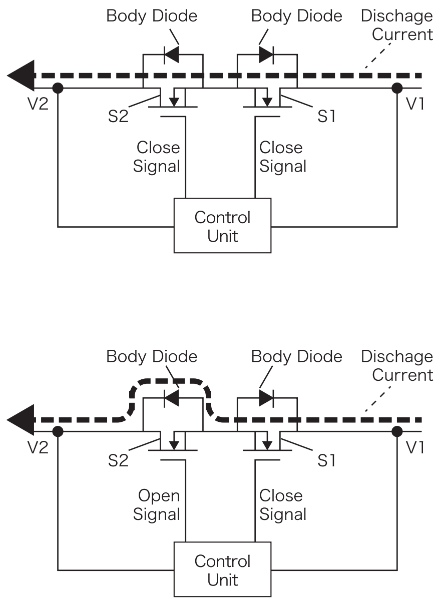


Switch-Failure Diagnosis with Series-Connected FETs

A 12V battery, which is not for engine startup, may employ a field-effect transistor (FET) as the switch because not a very large current flows on the charge-discharge path. Here, a pair of FETs may be arranged in series on the charge-discharge path with the body diodes oriented in reverse of each other (top, ●Fig. 2). During normal operation, discharge current from the battery assembly is supplied to the load while switch S1 (for blocking battery discharging) and switch S2 (for blocking battery charging) are both closed.

At switch-failure diagnosis, when the BMS signals switch S2 to open (bottom, ●Fig. 2), the load is supplied a discharge current through the body diode of switch S2, and a voltage drop occurs owing to the body diode. However, if switch S2 failed closed, switch S2 remains closed (top, ●Fig. 2) even when the BMS signals switch S2 to open. In this case, the difference between battery-assembly voltage V1 and load voltage V2 is small because no voltage drop occurs owing to the body diode compared with when switch S2 is open (bottom, ●Fig. 2). The BMS detects that the voltage drop across the switch terminals at this point is small and can thus determine that switch S2 failed closed[3]. Here again, switch-failure diagnosis can be performed without interrupting power supply to the load.

●Fig. 2 Switch-Failure Diagnosis with Series-Connected FETs



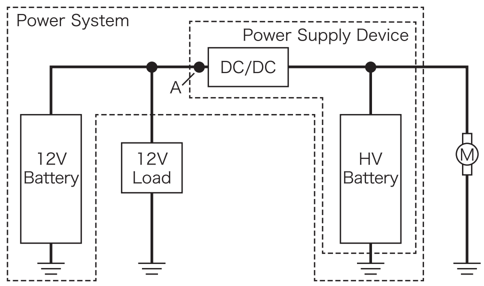
Switch-Failure Diagnosis in a Complex Power System

The 12V battery remains desirable for a variety of applications, particularly automotive. In this area, a 12V battery —which is equipped with a BMS and supplies power to the vehicle's accessories, e.g., the brake, door-lock, car navigation/infotainment systems— is needed that performs switch-failure diagnosis without interrupting the supply of power to the load. The power system of an electric vehicle includes the 12V battery and a high-voltage (HV) battery that supplies electric power to motor M that drives the vehicle (●Fig. 3). The on-board 12V load is connected to the 12V battery and to a HV power-supply device that includes a DC-DC converter and the HV battery.

At switch-failure diagnosis of the 12V battery, the DC-DC converter supplies lower-voltage power to point A. At the same time, the BMS operates switches S1, S2 and detects changes in the current value to determine whether the switches operated correctly. Although opening one of the switches breaks the path from the 12V battery to the 12V load, power is being supplied to the 12V load from the HV battery[4]. Therefore, the 12V load, i.e., all the vehicle's accessories can still operate reliably during switch-failure diagnosis of the 12V battery.

In this article we explored examples of switch-failure diagnosis performed by the BMS, which we developed for application to the 12V battery. As incorporating BMS becomes more widespread, GS Yuasa will continue to develop battery management technology that contributes to improving the reliability of battery-powered products.

●Fig. 3 12V Battery in a Complex Power System



1. https://www.gs-yuasa.com/en/technology/making_history/pdf/no12.pdf
2. Japanese Patent No. 5983171 (Filed in 2012); Patent Family: US Patent No. 9267992, US Patent No. 9746522, Chinese Patent No. 201310336635.4, German Patent No. 602013083618.3
3. Japanese Patent No. 6327278 (Filed in 2012); Patent Family: US Patent No. 9383412, Chinese Patent No. 201310059853.8, Korean Patent No. 10-1980848, German Patent No. 102013203545
4. Japanese Patent Publication No. 2021-166454 (Filed in 2020); Patent Family: US Patent Publication No. 2023/0152376, Chinese Patent Publication No. 115349212, German Patent Publication No. 112021002217

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