Part 03

Developing a Battery Control System

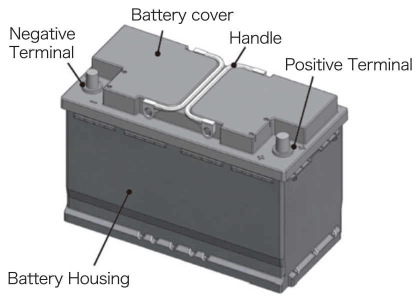
# Control Technology for the Battery in Idling Stop Vehicles

**Idling stop systems (also known as "start-stop" or "idle-stop" systems) provide a relatively small contribution to fuel efficiency and reducing $CO_2$ emissions compared to electrical and hybrid vehicles. However, these systems are able to minimize the development and system costs of the entire vehicle. Idling stop vehicles that employ lead acid batteries have been quite popular in Europe and Japan. Recently, however, with pressing environmental concerns manufacturers have begun to replace lead acid with lithium ion batteries in these systems.**
**In 2013 GS Yuasa developed a lithium-ion cell-based 12-volt battery assembly (hereafter, 12V battery) for use in idling stop vehicles (●Fig. 1)[1]. We then embarked on developing the various kinds of control technologies that could be applied to this kind of 12V battery.**
**In this article, we discuss the 12V battery concept and the type of technology used to prevent the battery from loosing the ability to operate.**

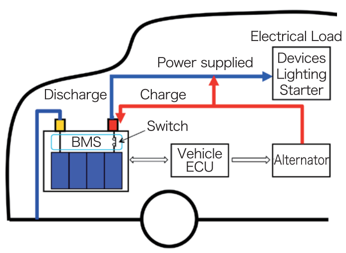
## 1. Overview

GS Yuasa's 12V battery incorporates a battery assembly consisting of four lithium iron phosphate battery cells (LFP battery cells) connected in series, and a built-in battery management system (BMS). The 12V battery is roughly half as light as a lead storage battery of the same size.
As shown in ●Fig. 2, various loads are connected to the 12V battery such as automotive devices and lighting, and the starter; an alternator, which is the generator, is also connected to the 12V battery. While the engine is running, the alternator generates the power that is supplied to automotive devices and lighting and used to charge the 12V battery. When the engine stops, the 12V battery discharges to supply power to the electrical loads. When the engine starts up, the 12V battery also supplies a large electric current to the starter.
The 12V battery must have sufficient discharge capacity to supply stable power to automotive devices and an ability to charge quickly via the alternator (i.e., charge acceptance) even in travel patterns that require frequent idle stops, such as traveling through town. The 12V battery is also expected to reliably start the engine in any situation, i.e., is expected to have a certain level of output performance, and maintain this output performance over a long period.
The BMS monitors the current through the 12V battery, the voltage of each LFP battery cell, and the internal temperature of the 12V battery to estimate the SOC of each of the LFP battery cells and balance the SOC of the LFP battery cells. The BMS communicates with the vehicle's power management electronic control unit (ECU) and transmits information such as current, cell voltage, temperature and other information that is used for determining the appropriate time for an idling stop and the appropriate amount of charge to be supplied by the alternator. The LFP battery cell supplies the power used to operate the BMS.

●Fig. 1 Appearance of the 12V Battery




●Fig. 2 Automotive Power System Block

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## 2. Preventing Disablement of the Battery

The 12V battery will supply a weak electrical current, also called a dark current to the automotive devices while the vehicle is left parked and the alternator is unable to charge the 12V battery. The BMS continues to monitor the battery while the vehicle is parked and consumes a small amount of power from the LFP battery cells. If the automotive devices are receiving dark current, since the BMS is also consuming power, the 12V battery will eventually be unable to start the engine, i.e., the battery will be disabled if the vehicle is left parked for a long time.

As illustrated in ●Fig. 3, the 12V battery includes a switch to prevent overcharging and overdischarging of the LFP battery cells. GS Yuasa devised the technology for effectively preventing the battery from becoming disabled via opening and closing the switch as appropriate.

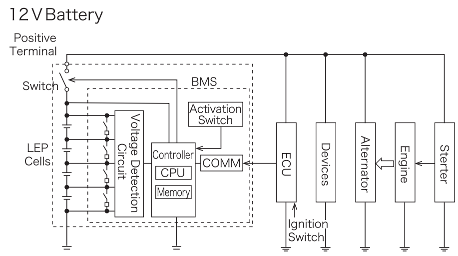
The switch depicted in ●Fig. 3 is provided between the positive terminal of the 12V battery and the LFP battery cells; this may be, for instance, a relay. This switch is normally closed to allow the alternator to charge the battery and to supply power to the automotive devices or the starter. A signal from the controller in the BMS causes the switch to open and thus break the power circuit.

As illustrated in ●Fig. 4, the so-called open-circuit voltage (OCV) starts to decrease once the SOC for each of the LFP battery cells starts decreasing due to the dark current supplied while the vehicle is parked or due to power consumption from the BMS. If the OCV falls below the lower limit Vth3 for starting the engine (i.e., an OCV corresponding to the "minimum SOC"), the 12V battery can no longer start the engine. Therefore, opening the switch at the moment the OCV is at Vth1, which is slightly higher than Vth3 (i.e., the OCV corresponding to a "power saving SOC"), stops the flow of dark current. The BMS may be switched from an operating mode to a deep sleep mode simultaneously to minimize the power consumption of the BMS.

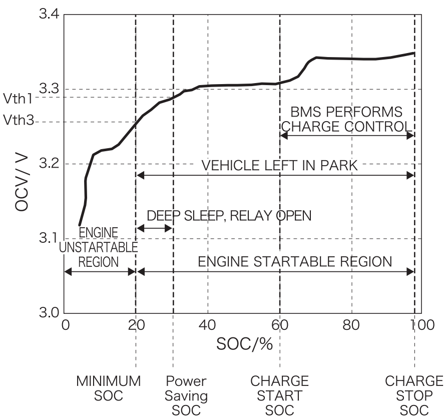
There is significantly less decline in the SOC and OCV of the LFP battery cells once the supply of dark current to the automotive devices is blocked and the BMS is in deep sleep mode. As such, it takes a much longer time for the system to transition from power saving SOC to the minimum SOC. This technology makes it possible to prevent the battery from becoming disabled even when the vehicle is left parked for a long time and the alternator cannot charge the 12V battery. Note that the state of the ignition switch may be detected, or an external signal may be provided to close the open switch.

This article provided an overview of the 12V battery used in idling stop vehicles that employ lithium ion cells as well as a battery management system for preventing disablement of the battery. GS Yuasa will continue to further develop technologies that achieve battery control systems able to withstand severe operating environments while supporting a high level of vehicle electrification.

●Fig. 3 BMS and Switch in the 12V Battery[2]




●Fig. 4 Switch Control Timings




1. GS Yuasa Technical Report Volume 10, No. 2, published 2013
2. Japanese Patent No. 6234127, European Patent No.2720309, US Patent Nos. 9165736, 9463699, 9701207, Chinese Patent No. 201310466821.X (Filed in 2012)

For inquiries, contact:
Intellectual Property Division,
GS Yuasa International Ltd.