Determining Accurate State-of-Charge with the MPF4279x Series (Part II)

Introduction

When designing a battery management system (BMS), designers can face challenges when obtaining an accurate estimate of the battery's state-of-charge (SoC), which is the level of a charge a battery has in relation to its capacity.

This article is the second of a two-part series discussing SoC estimations. Part I explored the complex application of battery conditions in SoC estimation, as well one method to estimate the SoC. Part II will discuss additional methods to estimate SoC and introduce the MPF4279x series.

Introduction to SoC Algorithms

There are three methods to calculate SoC: the open-circuit voltage (OCV), ampere-hour integration, and voltage-current hybrid method. Part I of this series discussed the OCV method, while this article will discuss the remaining two methods.

Ampere-Hour Integration Method

Conventional SoC estimation approaches generally use the ampere-hour integration method, otherwise known as the current integration method or Coulomb counting method. During the battery charging and discharging processes, the SoC is estimated by accumulating the amount of charge going in and out of the battery. All the coulombs entering the battery during the charging process remain in the battery. Meanwhile, the power that flows out during discharging processes causes the SoC to drop.

The current SoC (SoC_{NOW}) can be calculated with Equation (1):

$$SoC_{NOW} = SoC_{PAST} - (I_{NOW} \times \Delta t) / Q_{MAX} \tag{1}$$

Where SOC_{PAST} is the latest SoC estimate, I_{NOW} is the real-time current, t is time, and Q_{MAX} is the maximum capacity. Note that in this equation, a positive current is used for discharge and a negative current is used for charge.

Compared to the OCV method, the ampere-hour integration method is more accurate. However, in this method, the algorithm simply records the charge flowing in and out of the battery while ignoring any changes in the battery's internal state. Since different battery models have varying self-discharge rates that also depend on the battery's SoC, temperature, and cycle history, an accurate self-discharge model requires a significant amount of time to collect data with precision errors.

Additionally, the current measurement can be inaccurate, which can result in the accumulation of SoC estimation errors that demand continuous calibration. If the battery has been inactive for a long time or the discharge current experiences variations, there may be additional errors in the estimate.

Voltage-Current Hybrid Algorithm

The OCV method is not practical for actual operating conditions, and the ampere-hour integration method does not effectively eliminate errors in SoC estimation. As time goes on, it can become more difficult for designers to accurately measure SoC using one of these methods alone.

To mitigate the shortcomings of these traditional approaches, the OCV method can be combined with other methods to predict the SoC. The voltage-current hybrid model utilizes both the OCV and ampere-hour integration methods.

MPS implements a refined version of this method and tracks two variables (the temperature and internal resistance) to accurately measure SoC within 2% of its actual value. This method not only models the battery OCV but the equivalent series resistance and diffusion as well. Figure 1 shows this method.

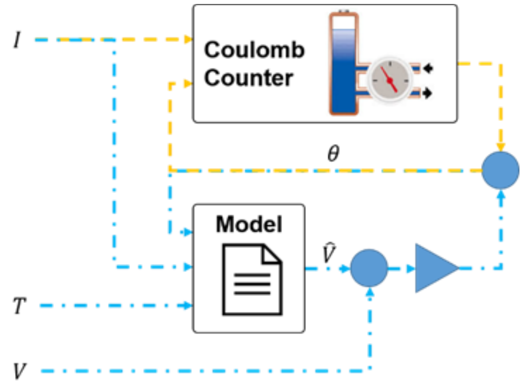

Figure 1: Voltage-Current Hybrid Method

Battery Management with the MPF4279x Series

The MPF4279x series (including the MPF42791, MPF42797, MPF42790, MPF42792, and MPF42795) are a family of fuel gauge solutions that combine the advantages of the OCV and ampere-hour integration methods to accurately predict SoC. These advanced battery fuel gauge chips can be paired with any type of analog front-end (AFE) by leveraging the system's microcontroller (MCU) to provide battery pack readings. A few features of this family are listed below:

- Can support up to 16-cell batteries, including a wide variety of lithium cells
- Calculates SoC for each battery to better predict the entire battery's full and empty conditions
- Provides an external MCU that can meet the computing requirements
- Supports a simple, easy-to-design peripheral circuit with 5 external LEDs to display the power (for the MPF42790 and MPF42795 exclusively)

Figure 2 shows the MPF42790's functional block diagram.

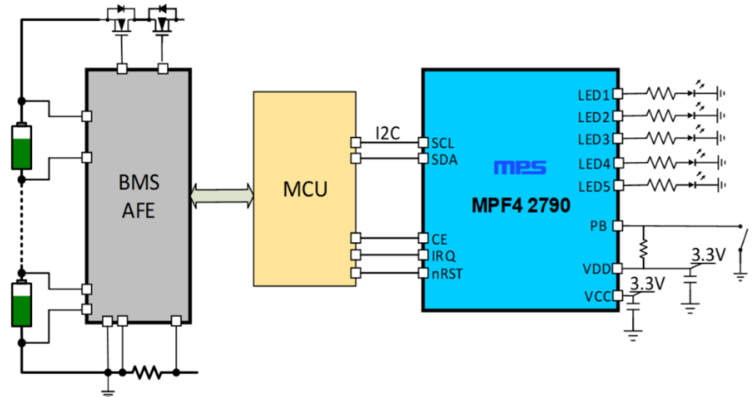

Figure 2: MPF42790 Functional Block Diagram

Table 1 compares these five solutions.

Table 1: The MPF4279x Series

	MPF42790	MPF42791	MPF42792	MPF42795	MPF42797
Level LEDs?	Yes	No	No	Yes	No
Battery pack cells	2 to 16	2 to 16	2 to 16	2 to 10	2 to 10
Nominal battery pack voltage	7.4V to 60V	7.2V and 57.6V	7.4V and 60V	7.4V and 37V	7.4V and 37V

Conclusion

With the increasing demand of battery-based applications, accurate SoC estimation is crucial for effective battery management. In this article, we discussed common challenges to estimating SoC and expanded on the voltage-current hybrid method with the MPF4279x series, a new family of fuel gauges designed for a wide range of applications. Explore MPS's robust portfolio of battery management solutions for more charging solutions.