Extend Runtime of Portable Devices Via Accurate, Low I_Q Battery Fuel Gauging

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June 2018

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Abstract

The increasing prevalence of wearables and small, connected devices are driving demand for lighter and smaller batteries. Consumers of these products, in turn, expect reliable information on the status of the batteries inside, not to mention long battery life. Deriving accurate battery state-of-charge (SOC) information can be a challenging process, as well as a lengthy one if battery characterization is required. This paper discusses capabilities to consider when evaluating fuel gauge ICs, and examines a new solution that delivers accuracy without characterization along with a high-side R_{sense} option for distributed ground systems.

Introduction

Fuel Gauges a Key to Better Device Runtime

Advanced fuel gauge ICs deliver high accuracy without battery characterization

For many portable consumer devices powered by lithium-ion batteries, battery life ranks high as a criterion that influences satisfaction levels. Users want their smartwatches, wearables, and similar devices to run for extended periods between charging—and they want to know how much battery life they've got left at any given time. After all, poor fuel gauge accuracy means premature shutdown if the remaining battery capacity is underestimated or abrupt shutdown if the remaining capacity is overestimated. Yet the design challenges here are clear: smaller devices mean smaller batteries with less capacity.

So, how can you squeeze the last drop of energy out of batteries in order to maximize device runtime?

The right battery fuel gauge IC can help you meet your goals. Fuel gauges determine battery SOC and state-of-health and predict the amount of time, based on specific operating conditions, that the battery can continue powering the device. Not all fuel gauges are created the same, however. Traditionally, fuel gauges have been very dependent upon the specific battery type. As such, designers have had to tailor their gauges to each battery, a laborious and lengthy process requiring characterization of the battery in a lab under various load and temperature conditions. Considering the time-to-market pressures of the internet of things (IoT) market, this is not an ideal situation. Read my white paper, "Accurate Technology for Easy, Secure Fuel Gauging You Can Trust," for a detailed discussion about fuel gauging methodologies using coulomb-counting and simple (or immediate) voltage measurements.

Newer, more advanced fuel gauging technology eliminates the tradeoffs of traditional methods to deliver high accuracy without characterization. Let's take a closer look at the key design challenges for portable electronics and what to look for in a battery fuel gauge to ensure that it will address these challenges.

Keeping On-the-Go Customers Happy

New high-performance devices utilize elaborate power management techniques to extend battery life. These techniques require the processors inside to remain in a very low-power state until some user interaction triggers the processor to ramp up quickly. While this is necessary for product performance, this approach also draws huge peak loads. Without proper battery management, there's a significant risk of the battery getting overwhelmed by the fast ramp-up and crashing because it is unable to provide these huge currents. **Dynamic battery power technology** that can guide the system in throttling the processor optimally based on the battery state can mitigate the effects of these power management techniques. Such technology can effectively maintain battery voltage above a safe threshold while maximizing performance and extending runtime.

Another consideration affecting runtime is the fact that many portable, battery-powered devices spend a lot of their time in sleep mode. If you're sitting down and working, for instance, your fitness tracker isn't tracking steps or activity and is instead standing by until an action is triggered. That's why it's important for all of the ICs in the device to have **low quiescent current**. High quiescent current drains small batteries continuously, significantly impacting runtime.

Many mobile devices now have fast charging capabilities, such as direct charging. These techniques call for careful monitoring of the captive battery, as the exact battery voltage needs to be known for safe fast charging to proceed. High currents are involved here, as are voltage drops that can lead to errors in voltage measurement. Embedding a fuel gauge in the battery pack to accurately monitor voltage, current, and temperature fulfills the needs here. While we're on the subject of safety, another consideration is having a means to uniquely identify the fuel gauge in order to prevent the use of unsafe aftermarket clones. To address this concern, some of today's fuel gauge ICs include **unique IDs that enable cloud-based authentication** in conjunction with another unique ID on the host side. For example, if a user has installed a cloned battery pack in his or her mobile phone, the device would be alerted of such after communicating the battery's and host's unrecognized serial number combination to the cloud-based authentication database. The device can be designed to restrict charging or prevent other unsafe activities when such situations occur.

Taking the High Road

For most applications, it really doesn't matter whether current sensors are mounted on the high side or low side. That's why the industry has not really embraced high-side sensing. For some applications, however, low-side current sensing isn't appropriate—you have to go high. Where sensor placement does have an impact is in applications with a distributed ground system, such as telematics. If you place a current sensor in the ground line, it's difficult to ensure that you are measuring all of the current given the distributed nature of the ground system. **High-side current sensing** keeps the ground plane intact. This approach is beneficial even in normal systems as it simplifies ground plane design. (Low-side current sensing requires extra care in how and where signals are connected around the sense resistor.) Another example where high-side sensing would be used is when the application shares R_{sense} with the charger.

There are some common-mode tradeoffs to consider when applying high-side sensing. For example, when you're measuring any signal centered around zero, you'll encounter fewer problems with accuracy given the error budget. However, if the signal is centered around a higher voltage, say 4V (normal in Li+ battery), then since you are riding on a very high signal level to begin with, it can be difficult

I^2C interfaces simplify communications for devices with more than one battery

to measure the signal accurately around this higher voltage level. Modern design techniques do try to minimize the effects of this tradeoff.

Simplifying Communications with Multiple Batteries

Some applications require two batteries. Smartglasses are an example, with a battery in each temple. These types of electronics call for a complex switching mechanism to first charge one battery and then the other. Unless the two batteries are hard-connected, and also since both batteries may not be in use in parallel, two fuel gauge ICs will be needed. In such applications, it's beneficial to use a fuel gauge that is designed with **separate I^2C addresses**. This way, both fuel gauges can utilize the same I^2C bus and the host microcontroller can communicate with both. An alternative is for the host microcontroller to use separate I^2C ports to talk to each fuel gauge, which means that the microcontroller would need to have additional pins available for this, along with more than one I^2C port. What's more, designing these glasses with high-side sensing allows the use of the same uninterrupted ground plane on both sides of the glasses, thus simplifying the ground plane design.

Accuracy Without Characterization—All in a Small Package

In the latest addition to its portfolio of ModelGauge™ m5 fuel gauges, Maxim offers a solution that addresses the challenges of meeting the runtime and battery SOC accuracy requirements of small, portable electronic devices. The MAX17260 1-cell fuel gauge offers optional high-side current sensing and multiple I^2C address options. Its 5.1µA of quiescent current supports long device runtime. Its ModelGauge m5 algorithm provides industry-leading accuracy (depicted in Figure 1), while accuracy enhancements over previous-generation products provide improvements for 2+ week runtime applications. With its ModelGauge m5 EZ configuration, battery characterization is not needed for many types of cells. You can use the evaluation kit software to step through a few application details and generate the model in a few minutes. Maxim has run simulations with more than 300 different batteries and 3,000 discharges, generating results that show less than 3% error in more than 97% of most common test cases.

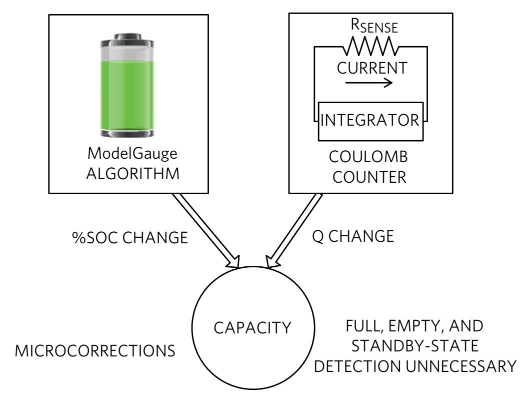

Figure 1. ModelGauge m5 EZ algorithm.

To extend the runtime of mobile devices by managing power based on the battery state, the MAX17260 features dynamic battery power technology. The dynamic battery power feature enables better runtime by allowing optimal CPU performance, throttling the CPU just enough to keep the system from crashing. For mobile devices with fast charging capabilities, the fuel gauge can be embedded in the battery pack to provide careful monitoring of voltage, current, and temperature. And to keep devices safe, the IC, available in a 1.5mm x 1.5mm WLP and a 3mm x 3mm TDFN package, has a unique ID for cloud-based authentication.

Figure 2 provides a block diagram showing the battery pack on the left connected to the host system on the right. The host system features an application processor that communicates with the fuel gauge IC mounted on the host side. The fuel gauge IC monitors the battery by connecting to the power terminals and, in some cases, to the thermistor inside the battery pack. The power management block on the host side contains the battery charger.

The accuracy of the MAX17260 is shown in Figure 3. Here, you can see the fuel gauge IC under various load conditions with effective runtimes of 3 to 32 hours and temperatures of 0 degrees Celsius to 40 degrees Celsius. Under these conditions, the SOC error is less than 1%. The fuel gauge also works well under more extreme conditions, such as very short runtimes (for example, 10 minutes and in -30°C operation).

Dynamic battery power technology, available in MAX17260, enhances device runtime

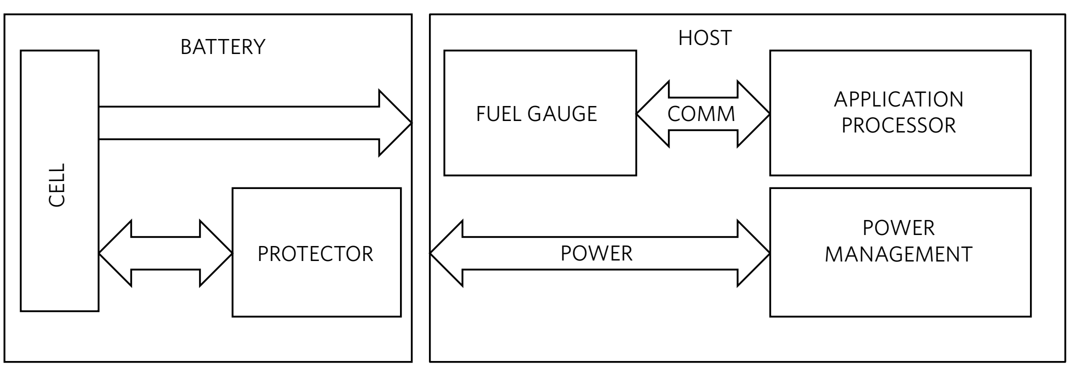

Figure 2. MAX17260 application block diagram.

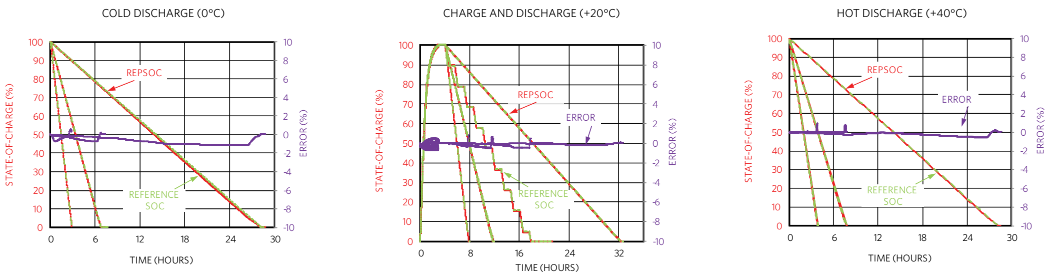

Figure 3. MAX17260 accuracy under various conditions.

Summary

Extending battery life for a portable electronic device can be as straightforward as implementing the right battery fuel gauge IC. High accuracy through careful monitoring of voltage, current, and temperature; low quiescent current; and the ability to manage power based on the battery state are among the key features to consider when evaluating fuel gauges. By taking measures to support longer battery life and provide accurate battery SOC information, you can ensure that your portable electronics will delight, not disappoint, your customers.

Learn More

Read the datasheet and other technical resources from the MAX17260 product page.

For more information, visit:
www.maximintegrated.com