From smartphones to smartwatches, fitness trackers, and gaming consoles, the mobile devices we use each day have become so pervasive that you could say we live in a battery-powered world. Indeed, the global market for portable, battery-powered products is anticipated to grow to US$865.4 billion by 2020, according to Global Industry Analysts, Inc. It’s no wonder, then, that battery fuel gauge technology has become so essential. We all appreciate an accurate reading of how much battery life is left in our electronic gadgets until the next recharging cycle.

**Figure 1** Smartphones are just one of many portable, battery-powered devices where accurate battery state-of-charge is essential for customer satisfaction.

Because temperature and load have such an effect on voltage, fuel gauging hasn’t typically been easy to do. Various scenarios are possible. For example, voltage could vary substantially because of load and temperature. Voltage changes could have too much delay. Or, open-circuit voltage (OCV) relaxation could have too much delay. Let’s take a closer look at different fuel gauging methodologies and their strengths and weaknesses.

**Why fuel gauging has been so time-consuming**

Traditional fuel gauging has involved a lengthy process. A power or battery specialist would work with a fuel gauge vendor to find a suitable model for their battery. Since the gauges are dependent on the battery type involved, the battery models would generally have to be tailored to each battery. Battery characterization under various load and temperature conditions would be required. The power/battery specialist would either use specialist test equipment at their own site, or send their
battery to the vendor for characterization. Once these steps were done, the specialist could then take the resulting custom battery model, plug it into the fuel gauge, conduct their evaluation, and finalize their design.

One fuel gauging method involves simple, or immediate, voltage. This method provides the greatest accuracy after the battery has been allowed to rest in an open-circuit state for at least two hours. Because of this, the simple voltage method is impractical to implement. Also, examining simple voltage alone isn’t a great indication of battery SOC because of the impact of cell materials and temperature on voltage.

Coulomb counting is another fuel gauging method to consider, particularly when short-term accuracy is important, as small errors have negligible impact. This approach measures the current going in and out of the battery at all times, accumulating the results. The estimated charge used by a device is subtracted from the total charge that can be held by the battery, indicating how much charge remains overall. Coulomb counting is, however, disadvantageous over longer periods of time because the counters do suffer from offset accumulation drift. As an example, consider a battery with capacity of 1000mAhr. With intermittent loads of 50mA for some time, followed by long periods of standby with nearly zero current, the battery gets drained over a period of four days.

Suppose the coulomb counter has a 1mA error (10µV offset in current measurement ADC and using a 10mΩ sense resistor). Extrapolated over the four days, that error becomes 96mAh. For a 1000mA battery, this error is equivalent to almost 10% of the battery capacity that may be over or underestimated. As you can see, a seemingly small error over a long period of time can actually create a large accuracy discrepancy. The device could shut down prematurely or crash abruptly as a result. For coulomb counting to be effective, the technique calls for constant corrections, typically when the battery is full or in an idle state, or when it reaches an empty state.

Coulomb counting comes with other challenges. Since the counter doesn’t know what empty and full are, the battery must cycle between empty and full for the system to know the battery’s capacity. Realistically, users rarely want to wait for the battery to be completely empty before recharging, so the empty-to-full or full-to-empty cycles happen infrequently.

**Simpler, less costly battery SOC assessments**

Today’s advanced fuel gauge ICs can determine battery SOC using voltage alone, which is much simpler and less costly than measuring currents or counting coulombs. Novel fuel gauge algorithms are able to tap into the relationship between SOC and OCV. Such technology runs real-time simulation that considers nonlinear behavior and the time effects of the battery, delivering highly accurate results without sensing current. This fuel gauge technology can even estimate OCV when the battery is under load using battery characterization and real-time simulation.

Newer fuel gauge ICs on the market blend traditional coulomb counting with a novel fuel gauge algorithm that further improves accuracy. These ICs can continually steer the coulomb counter in the current direction, performing fine corrections as needed along the way. While coulomb counters drift over time because of current measurement offset accumulation, this fuel gauge technology doesn’t suffer from offset accumulation error because it doesn’t measure current.

As a result, very good short-term accuracy along with long-term stability is possible. The latest version of these fuel gauge ICs feature a configuration wizard that allows designers to choose application parameters such as charge voltage, empty voltage, and termination current. Using these parameters, the tool then generates a battery model that works well for most types of commonly used batteries.
Accurate fuel gauging without battery characterization

Maxim offers proven battery fuel gauge ICs based on proprietary ModelGauge technology that delivers the market’s best SOC accuracy, longest battery runtime, fastest time to market, and robust safety/security in a small solution size. The ModelGauge algorithm converts real-time electrical measurements into usable SOC percentages and other battery information. With adaptive mechanisms, the fuel gauge ICs learn about battery characteristics so they can continually improve upon the accuracy provided. The latest version of the technology eliminates battery characterization, providing a configuration capability as well as features for age forecasting.

Figure 2 Maxim’s MAX17055 7uA one-cell fuel gauge implements an algorithm that eliminates battery characterization and provides tolerance against battery diversity for most lithium batteries and applications.

Summary

Building your mobile, battery-powered devices with accurate battery fuel gauging technology is critical for a good customer experience. Fuel gauging technologies have traditionally required time-consuming battery characterization, as the gauges have had to be tailored for each battery. Newer fuel gauge ICs with novel algorithms deliver highly accurate battery SOC without a characterization process.

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Also see:
• **Fuel gauge needs no battery characterization**
• **IC measures battery state-of-charge**
• **Select the right battery fuel-gauge for smart phones and tablets**
• **Microcontroller simplifies battery-state-of-charge measurement**