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Choosing Between Battery Gas Gauges and Battery Monitors to Track Charge Availability in Handheld Devices

Michael Vega
PMP - Portable Power

ABSTRACT

Some customers are unfamiliar with using battery monitors or gas gauges for their handheld portable applications. The intent of this application report is to provide information about TI product families that are excellent options when selecting a battery gas gauge solution.

Many electronic products continue to become smaller, more versatile, and mobile. Products such as smart phones, PDAs, music players, and portable gaming systems depend on reliable battery power. Given the importance of tasks that are accomplished with these devices, whether for work or entertainment, it is critical for end-consumers to know the remaining battery capacity before a device goes “dead”. For years, portable device system designers have used the battery voltage measurement method to determine the capacity of a battery in a given application. Although this method has been effective, it lacks accuracy. Because of the wide range of load characteristics among handheld devices, voltage measurement alone cannot determine capacity when the same device may have different power modes. A cellular phone that is browsing through different system menus is in a lower power mode than when it is accessing wireless features. The battery voltage can vary while at the same capacity level due to temperature, impedance differences, and discharge current.

If voltage measurement is an inaccurate scheme to determine remaining battery capacity, then what else is possible? One approach measures the charge added or removed in determining the capacity change. It is based on measuring the amount of energy that is flowed into or out from a battery. This is accomplished by constantly monitoring the current that is being supplied from a charger or drained by a load.

Given that current is related to charge as $i(t) = \frac{dq(t)}{dt}$, by measuring the integral of current over time, the capacity being added or depleted from the battery is known. Accurate tracking of the battery’s capacity requires that something monitor the current activity of the battery at all times. During any time that the current is not being measured, the net amount of capacity being depleted from the battery may be unaccounted. This could result in false expectations of how much energy remains in the battery for use in a given handheld device. The main processor of a handheld system should not be tasked with measuring current to accurately report battery capacity. Rather, an independent system can measure the current and process this information so that the main processor can use it to determine power management functions and also provide battery/handheld device information to the end-user.

Battery gas gauging is the process to collect data such as current, voltage, and temperature and then use this data to make decisions concerning power management and battery capacity reporting. A gas gauge system requires at least two components. As a minimum, one subsystem must collect current, voltage, and temperature data, and another subsystem analyzes this data to obtain the desired battery conditions. A gas gauging algorithm in a microprocessor is used to analyze the data. This algorithm is complex, due to the various characteristics among batteries that must be considered. Self-discharge and aging of batteries also must be considered when implementing gas gauging. A battery that is at rest may show decreased capacity after an extensive time because of self-discharge. As a battery ages, the impedance is higher, and hence decreases the total battery capacity that can be used.

Texas Instruments (TI) has several products that can be used to implement a gas gauge function. For handheld applications, the bq27x00 and the bq2622x families prove to be complete gas-gauge solution devices. These products are based on a system that contains an analog-to-digital converter (ADC)-based coulomb counter, an ADC for voltage and temperature measurement, and internal registers that can be accessed by the handheld device's main processor (host) through data communication lines. The integration of a small CPU and built-in, gas gauging algorithms is the basic difference between the bq27x00 and the bq2622x. The small CPU that is in the bq27x00 devices contains an advanced gas gauging algorithm developed by TI for single-cell, Li-ion applications. The bq2622x does not have this small CPU. With the bq2622x, the gas gauging algorithm is performed by the host. The host has to get the measurement data such as battery voltage, charge and discharge current, and battery temperature to calculate the remaining capacity and estimate the battery run time. Coulomb counters that have the internal CPU with a gas gauging algorithm are known as gas gauges, whereas coulomb counters without a CPU are known as battery monitors.

Figure 1 is a basic representation of the most essential components in a battery gas gauge circuit.

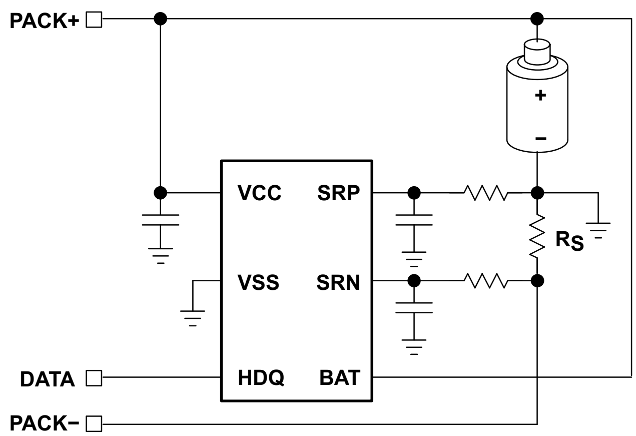

Figure 1. Simplified Gas Gauge Circuit

The simplified circuit in Figure 1 includes components that are shared between bq27x00 and bq2622x devices. The SRP and SRN pins are the inputs that measure battery charge and discharge current for the ADC coulomb counter. A low-value sense resistor (Rs) is connected to the ADC through low-pass filters. As current enters or exits the battery, the ADC integrates the potential difference across Rs in order to measure the capacity change. The polarity of the voltage at Rs determines whether it is a charge or discharge capacity change. The BAT pin is the input to the ADC that measures voltage. The measurement is done with respect to Vss. At least one pin of the IC is used for data communication. This pin is connected to the data line through which communication is exchanged between the gas gauge IC and the host. A battery pack containing a gas gauging circuit has three external connector pins, as a minimum.

Bq2622x and bq27x00 have different types of ADCs to implement the coulomb counting. The bq2622x has a voltage-to-frequency converter (VFC), and the bq27x00 has a Delta Sigma (ΔΣ) converter. Both counters are excellent even when measuring capacity based on a load profile that is not at a constant level at all times. The Global System for Mobile (GSM) load profile is likely to be characteristic for many cellular phone devices. This profile has a waveform similar to the one shown in Figure 2. If this waveform was captured using an ADC with a sample rate lower than 430 Hz, then it is likely that many of the pulses in which the current reached its maximum value were missed, and hence provide an under-estimation of the amount of current flowing into or out of the battery.

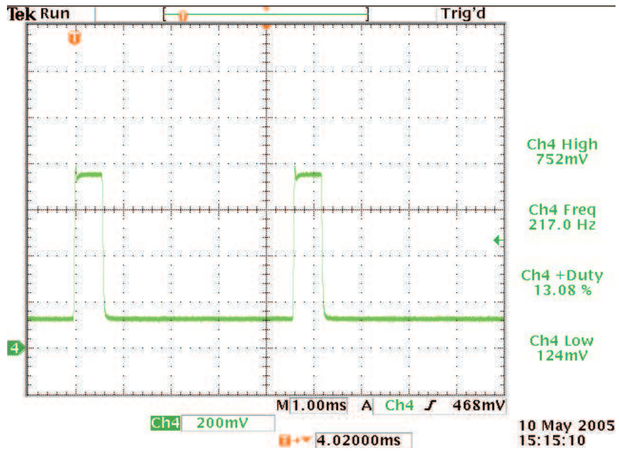

Figure 2. GSM Load Profile Across a 0.5-Ω Resistor

With the GSM load profile, the bq27x00 and bq2622x are capable of measuring all the current across a resistor. In Figure 3, the plot shows the decrease of capacity based on the GSM load profile. This load can be represented by a dc load of 411.28 mA. That constant current would account for 411.28 mAh of capacity for one hour. The bq27x00 and bq2622x were able to account for a decrease of 413.41 mAh and 406.57 mAh, respectively.

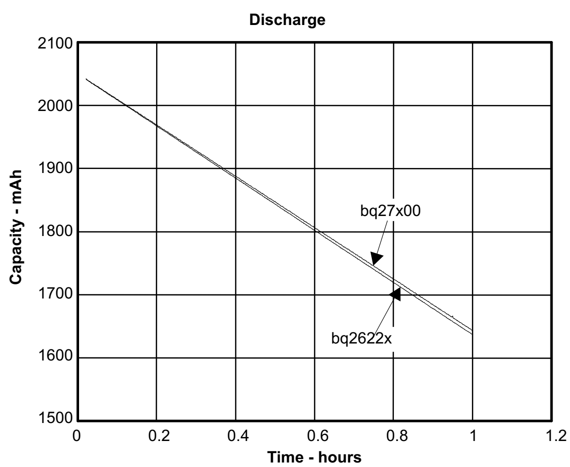

Figure 3. Capacity Measurement During Discharge

The bq2622x has registers that the host accesses to obtain battery voltage measurement, temperature measurement, counts for charge, discharge, and self-discharge. Other bq2622x registers have write access so that the host can clear register values in case of initialization or register maintenance. The host is responsible for making all calculations based on a gas gauging algorithm within the host. Although the bq2622x collects data continuously, the host may periodically process the data to determine the relative state of charge of the battery.

By having a small CPU containing an optimized gas gauging algorithm, the bq27x00 not only collects the data necessary for gas gauging, but it also uses the data to calculate values such as Relative State of Charge (RSOC), Time to Empty, and Time to Full. This information is stored within the IC. When the host needs the information, it can immediately obtain it by reading the appropriate RAM registers of the gas gauging IC and display it on a screen to the end-user.

Lithium-ion, single-cell applications such as cellular phones, MP3 players, and portable gaming systems that require the system microprocessor to manage complex tasks are the most suitable for the bq27x00. The system can concentrate more on running the main applications while allowing the gas gauge IC to handle all the battery management functions.

If the system designer desires to have more control and flexibility of how the gas gauging should be done and the wide range of applications possible, then the bq27x00 acting as a battery monitor or the bq2622x, along with a gas gauging algorithm written by the system developers would be the best fit. The bq27x00 also contains internal registers that can be used as a monitor. The host queries these registers directly, bypassing the internal CPU gas gauging algorithms. The advantage of using the bq27x00 in this manner is that some internal functions, such as charge termination detection, end of discharge voltage detection, board offset calibration, and average current measurement, can also be used.

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Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265