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COVER STORY

Novel Low Inductive Phase-Leg IGBT Module Eases Paralleling

At PCIM 2015 ABB has introduced the LinPak, a new open standard phase-leg type IGBT module with a rating of 1700 V and 2 x1000 A and a footprint of 100 mm x 140 mm. This type of module will set a new standard in power density. We designed the LinPak to accommodate chipsets from 1200 V up to 3300 V. The LinPak IGBT module features an exceptionally low stray inductance enabling the full utilization of advanced low switching loss IGBT chipsets and even future full Silicon Carbide switch solutions. In addition the LinPak is ideally suited for parallel connection with negligible derating, thus a large range of inverter power can be realized with just one module type. Together with the open standard concept this module fulfills a long wish of the industry in nearly all high power segments such as traction & CAV (commercial, construction and agricultural vehicles), wind-power & solar and industrial drives to name a few.
Full story on page 15.

Cover supplied by ABB Switzerland Semiconductors.

Making Battery Fuel Gauges Tell the Truth

A new and highly accurate technique for battery fuel gauging could help users of mobiles and other portable devices avoid the inconvenience and frustration of unexpected system shutdowns.

Steve Sheard, ON Semiconductor, USA

Battery-powered mobile devices have become vital to modern life. Users often need to continue operating their devices at low battery levels, and can suffer inconvenience if the system suddenly shuts down despite indicating that a few percent of battery energy still remains. Given the importance of knowing accurately how much energy is remaining in the battery at any time, accurate battery "fuel-gauging" is highly important. However, the coulomb-counting technique traditionally used in portable devices is not only inaccurate, leading to a high risk of unexpected shutdown, but is also subject to temperature-related errors and consumes precious battery energy that may be better utilized to power other functional circuitry.

Fuel gauging by coulomb counting

Coulomb counting uses a precision current-sensing resistor to monitor the battery output current continuously. The current is integrated over time, and the result is compared with the known maximum battery charge to calculate the remaining charge available.

Coulomb counting is inherently inaccurate because it is unable to detect battery self-discharge events, since the self-discharge current does not pass through the coulomb counter's sense resistor. Moreover, self-discharge events tend to increase the ambient temperature, which changes the resistance of the sense resistor thereby further impairing accuracy. In addition, the battery has to be fully charged every time for an accurate calibration. Further disadvantages of coulomb counting include the relatively high cost of the precision sense resistor, as well as the precious battery energy dissipated by this resistor as the sense current passes through continuously.

A coulomb counter may be accurate to within around 8 %. Hence if the indicator suggests 10 % of charge is remaining, the real value may be as little as 2 %. With such a level of inaccuracy, the user may become anxious about the remaining battery life even if the indicator shows 20 % or so of charge remaining. The worry of sudden plummets in indicated battery life only serve to add to the general sense of mistrust of the status information presented.

As the market waits patiently for improvements in battery technology (or indeed resigned to the status quo), and equipment designers conceive increasingly complex power-management schemes to conserve every possible scrap of battery energy, it is extremely important that the fuel gauge provides an accurate reading for the user while itself consuming as little of the battery's energy as possible.

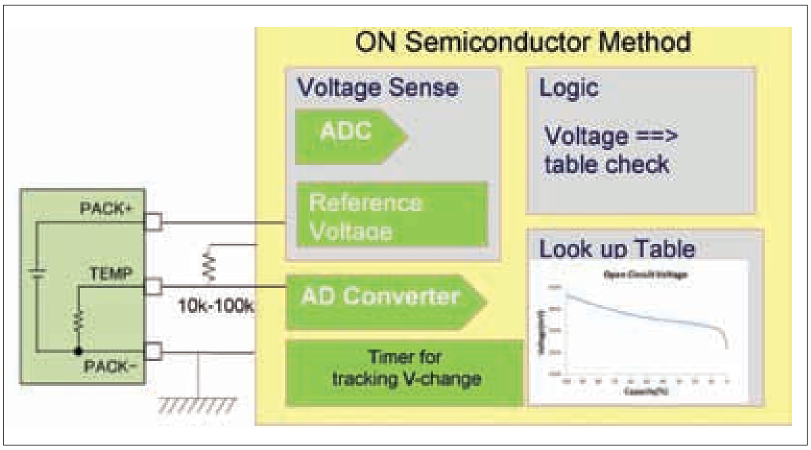

Figure 1: Voltage-sensing method for battery fuel gauging

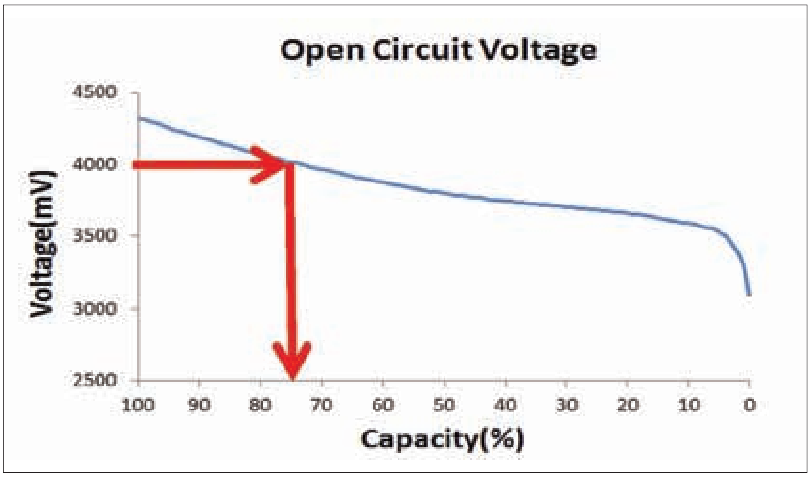

Figure 2. The remaining battery capacity is inferred from the measured voltage by referring to the battery reference table

A better way

ON Semiconductor has developed a proprietary method for calculating the remaining battery energy based on the voltage measured across the battery using a precision analogue-to-digital converter (ADC). Figure 1 illustrates a basic application circuit showing the major functional blocks of a fuel-gauging system using this technique.

A reference table describing the voltage-vs-capacity characteristic of the battery technology being monitored is stored in memory. By comparing the measured

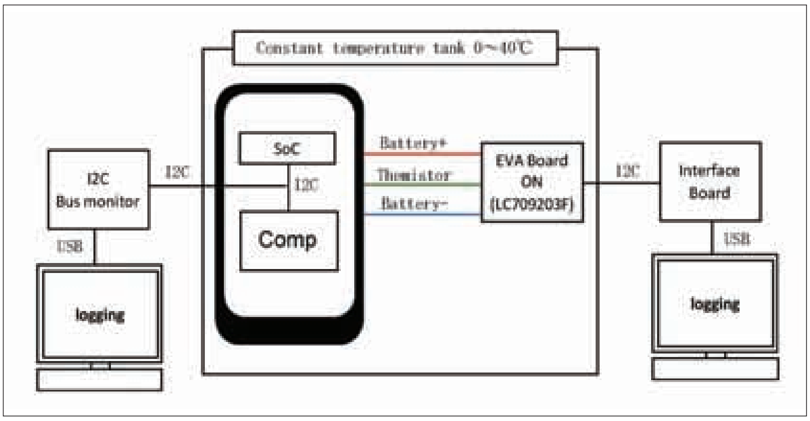

Figure 3. **Comparison of built-in smartphone battery fuel gauge and voltage measurement technique using LC709203F**

voltage with values stored in the table, the remaining battery capacity can be calculated. Figure 2 illustrates the principle: if the measured voltage is 4.0 V, comparison with the reference table suggests 75 % of battery charge is remaining.

Repeated voltage measurements are taken at known time intervals. The battery temperature is also monitored. The time remaining before the battery will be completely depleted can then be calculated, based on the voltage and temperature measurements and the changes in the voltage recorded at the known time intervals. More frequent readings are taken at lower battery voltages, to ensure accurate predictions as the remaining battery life becomes shorter.

By measuring the voltage across the battery pack, this approach is able to take account of battery self-discharge events. Moreover, the battery does not need to be fully charged for calibration. The remaining battery life can be calculated accurately even if the battery is only charged to 50 %.

Because measurements are taken at intervals, the monitoring circuitry does not need to be active continuously. This allows the fuel gauging circuitry to enter energy-saving sleep mode in between measurements. The active power consumption can also be reduced, in comparison with a conventional coulomb counter, since no sense resistor is needed.

Operation at low ambient temperatures is known to have a significant effect on the performance of Li-ion batteries. In particular, the battery impedance changes as the temperature falls to 0°C or lower, resulting in increased battery voltage drop when discharge current flows. A unique correction algorithm in its LC709203F battery-voltage sensing fuel gauge IC helps ensure fuel-gauging accuracy remains within 2.8 % over a wide ambient temperature range and at all battery voltages.

Experimental results

To compare fuel gauging using the LC709203F with the performance of a coulomb counting circuit, a smartphone with a new battery was adapted to allow the positive and negative battery connections and the thermistor output of the battery pack to be connected to the device while allowing the smartphone's built-in fuel gauge to continue operating. Data loggers were used to record the output of the built-in fuel gauge, which was monitored via the smartphone I²C bus, and the output of the LC709203F. The smartphone was placed in a constant-temperature tank at 0°C, and operated in airplane mode with the backlight turned on. Figure 3 illustrates the experimental setup.

Figure 4 shows the results of the comparison. The accuracy achieved using the LC709203F is better than 2.8 % for the duration of the test, and is better than 2 % at the lowest levels of remaining battery energy. The standard fuel-gauge system operates with varying levels of error and reaches its highest level of more than 6 % as battery energy nears depletion. From the user's point of view, greater accuracy is desirable at lower levels of battery energy, to be able to predict when the equipment may shut down.

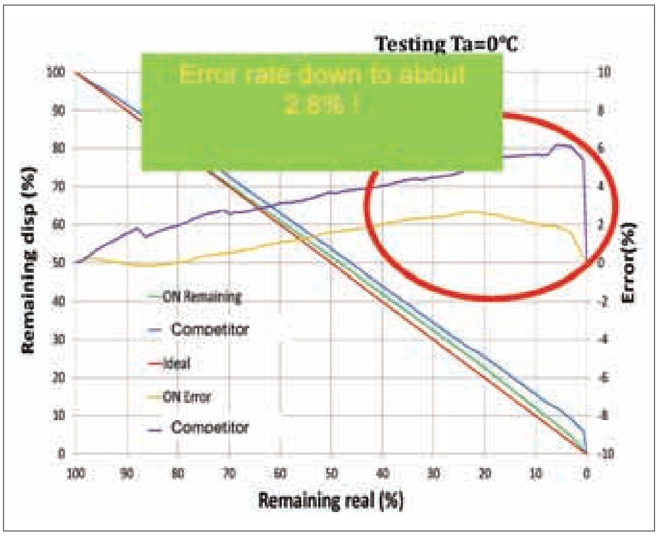

Figure 4. **Results of comparison test**

Size and power savings

The LC709203F allows effective fuel gauging using only one external component, whereas alternative devices may require two to five, or as many as 14, additional components. This delivers a valuable saving in Bill Of Material costs and design time, and also increases reliability. Moreover, the 1.76mm x 1.6mm package is about 45% smaller than alternative devices. Combined with the reduced component count, this allows the overall PCB footprint of the fuel gauge circuit to be reduced by around 77%. This can represent a crucial gain for smartphone designers who continually battle to squeeze in all the design elements to provide the functionality and user interface demanded by consumers, leaving little space for the components that actually make it all happen.

Total power consumption is also lower. The LC709203F operating current of 15 µA is approximately 1/10th that of the closest competing device, which draws 118 µA. In addition to this improvement of over 87 % in active consumption, the LC709203F draws up to 60 % lower current in sleep mode.

Conclusion

The relatively poor accuracy of conventional coulomb-counting battery fuel gauges leaves users of today's mobile devices vulnerable to inconvenient interruptions when using their devices, particularly when working close to the limits of remaining battery energy. A new technique that uses precision sensing of battery voltage, with error correction and temperature compensation built in, promises a more accurate, cost-effective and energy-efficient solution that will enable users to manage their mobile batteries more effectively.