Application Report
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Using the bq27x00 With a Primary Cell Battery

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ABSTRACT

The bq27x00 contains an accurate coulomb counter and has algorithms to determine the available capacity and to dynamically compensate the available capacity for temperature and discharge rate. If direct drive from the gauge to an LED display is not required, the bq27x00 can be used as a complete gas gauge solution for a primary cell battery. Although the bq27x00 was designed for a single-cell rechargeable lithium-ion or lithium-polymer battery, it can be used for any primary cell chemistry because charging efficiency is not important and algorithms specific to the lithium chemistry are not needed. It also can be used with a multicell battery with the addition of an external LDO to provide a regulated Vcc and a voltage divider or active attenuator to provide voltage to the BAT input. The bq27x00 automatically enters low-power sleep mode if a communication line is low for at least 20 seconds. The gauge can provide time-to-empty (TTE) in minutes, nominal available charge (NAC), relative state-of-charge (RSOC), and many other parameters.

1 Coulomb Counter Only Option

Used as a coulomb counter, the bq27x00 simply measures the capacity removed from the battery by using the initial last measured discharge (ILMD) value as the design capacity of the battery. The ILMD value should be programmed for the minimum available capacity from the battery under worst-case operating conditions. The minimum available capacity should consider both maximum load and minimum temperature operational conditions. The disadvantage of this approach is that the minimum available capacity may be severely reduced at cold temperature and thus would prevent the ability to obtain longer run times when the system is not used in a cold temperature environment.

2 Coulomb Counter With Discharge and Temperature Compensation Option

If temperature compensation (TCOMP) and discharge compensation (DCOMP) values are programmed to reduce the available capacity at cold temperature and high discharge rates, the system is able to achieve longer run times when used in a typical operational scenario. ILMD can be programmed for the minimum available capacity for the battery with a minimum operating load and a nominal operating temperature and TCOMP and DCOMP values can be programmed for the appropriate temperature and discharge rate capacity compensation values to dynamically adjust the remaining capacity prediction according to the actual use environment.

The compensated available capacity with temperature (and discharge rate), or CACT, is reduced below the NAC value at high discharge rates according to the programmed DCOMP parameter. If the discharge rate is later reduced so that there is less discharge rate compensation, the CACT value remains depressed until NAC decreases to the point where the NAC and CACT difference matches the capacity reduction at the lower load current. CACT is also reduced below NAC at cold temperature according to the programmed TCOMP parameter. However, the CACT reduction due to temperature is not held and CACT may rise immediately with a temperature increase. The temperature compensation calculation is independent of load current; so, the CACT compensation coefficient should be chosen to temperature-compensate the capacity at the highest expected steady-state load current. The actual capacity reduction is less at lower load currents, so this compensation setup will take care of the worst-case load and temperature conditions. The CACT value is used to compute a compensated state-of-charge (CSOC) value that provides the rate and temperature compensated capacity as a percentage of LMD.

The TTE value indicates how much run time is available with the present load and temperature conditions. The user may input an at-rate (AR) load current to represent some future load condition. The maximum load current (MLI) is initialized from EEPROM, but is increased to the value of any measured load current that is higher. The user may read the at-rate time-to-empty (ARTTE) or maximum load time-to-empty (MLTTE) values to obtain the run time for these load conditions that may occur at some future time. Both ARTTE and MLTTE compute the available capacity based on the present temperature, but use the DCOMP value to compute the compensated available capacity at the corresponding AR or MLI load condition.

3 End-of-Discharge Voltage Compensation

The previous discussions have been made without use of any voltage measurements and the BAT pin could be tied to Vcc in the application circuit if that performance is satisfactory. It may be possible to gain some increased run time and/or confidence of the remaining battery capacity by using voltage measurements near the end-of-discharge to correct the available capacity somewhat before the battery is discharged to empty. The BAT pin only handles a maximum voltage of Vcc, so voltage measurement of a multicell battery may need either a voltage divider or active voltage attenuator circuit. Either approach consumes some power, even when the system is off, so this may not be an acceptable solution. Alternatively, the BAT input may be connected to the first cell tap above the negative end. This approach allows measurement of the battery voltage without the power consumption of a voltage attenuator, but assumes that the battery cells are balanced well enough to use the single-cell voltage measurement for the end-of-discharge capacity correction. The LDO must provide a Vcc voltage at least as high as the maximum BAT voltage.

The bq27x00 attempts to synchronize the NAC value to last measured discharge (LMD)/16 at the first end-of-discharge voltage (EDV1). When the BAT voltage drops below the programmed EDV1 threshold, the gauge makes an immediate reduction of NAC to LMD/16 unless NAC is already at or below that value. So, if the capacity of some batteries is less than nominal, or some hard-use conditions have degraded the capacity of the battery, the reported capacity could be corrected to 6.25% of LMD. If a 6.25% capacity value is sufficient notice to the user, the ILMD could be programmed to a more nominal capacity value instead of a worst-case minimum and allow a greater run time from a nominal battery. The bq27x00 also adjusts NAC to zero when the final end-of-discharge (EDVF) threshold is reached.

If NAC decreases to LMD/16 prior to when the BAT voltage drops below EDV1, NAC may be held at the LMD/16 value until the EDV1 threshold is detected. Holding NAC at LMD/16 is only done if the valid discharge flag (VDQ) is set. For the primary cell application, it is recommended that this synchronization be avoided by clearing VDQ. This can be done by sending a partial reset command after initializing the gauge to full after a fresh battery is connected. This also disables learning a new LMD value when the EDV1 threshold is detected. The compensated available capacity with discharge (CACD) value is held at the LMD/16 value until EDV1 is detected unless there is no discharge compensation (CACD - NAC). This means that the EDV1 threshold should be determined as the voltage threshold corresponding to a 6.25% remaining capacity value at maximum expected steady-state load and a nominal operating temperature. The temperature compensation allows the CACT value to drop below the LMD/16 value, so that the EDV1 threshold does not need to account for cold temperature operation

4 Host Side Versus Battery Side and Initialization

The bq27x00 can be used in either the host or the battery for this application. If the gauge is installed in the battery, the gauge is not reused after the battery is expended. If the gauge is in the host, the host needs to have the capability to reinitialize the gauge to a full condition after a fresh battery is installed. This solution is practical if the new battery has the same capacity as the replaced battery, as the ILMD value cannot be adjusted from the value programmed in EEPROM.

Initialization is performed by first sending a DONE command to initialize the battery to full (NAC=LMD). This command requires setting bit 4 in MODE and then sending a 0xA9 key value to CTRL. After CTRL is cleared, indicating that the requested action has been performed, a partial reset (PRST) command to clear VDQ, EDV1, and EDVF flags and initialize other parameters should be sent. This command requires setting bit 3 in MODE and then sending a 0xA9 key value to CTRL.

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