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Building a Superior Battery Monitor With the bq27x00

PMP Portable Power

ABSTRACT

The bq27x00 is a complete gas gauge solution for lithium-ion and lithium-polymer batteries. The bq27x00 also has internal registers and control commands that enable the host to use it as a battery monitor. A battery gas gauge solution can be built one of two ways: ignore all algorithms built into the bq27x00 and use the primitive functions to build a fully customized solution, or use some of the higher level functions, such as self-discharge capacity loss estimate, taper current full battery detection, and end-of-discharge detection to build a semi-custom solution with less development time. An accurate direct reading of average current that is updated every 5.12 seconds, even at light loads, and a built-in digital magnitude filter (DMF) function, enable the host to build a more complete gas gauge solution with superior performance than is possible using other battery monitors. This superior solution may also be achieved without requiring significant communication or processing bandwidth from the host. The ability to directly read the capacity value using the built-in bq27x00 algorithms can be valuable during initialization of the host after the battery pack has been removed and externally charged or replaced with a different pack. The automatic sleep function of the bq27x00 can reduce the power consumption when the system is off, or the battery pack is removed. The host may choose to use either an HDQ (bq27000) or I^{2}C (bq27200) communication protocol.

1   Battery Monitor Capacity Register

The bq27x00 contains a 16-bit battery monitor capacity register (BMCR) at addresses 0x3e (low byte) and 0x3f (high byte). The BMCR increments with charge and decrements with discharge at the rate of 3.57 µVh per count. The bq27x00 firmware does not hold or make adjustments to the BMCR register during normal gauge operation, including overflow or underflow maintenance. There are two host commands for maintenance of the BMCR. To clear the BMCR, the host can write a command code of 0x63 to address 0x00. To set the BMCR to a desired value, the host can write the desired BMCR value to addresses 0x03 and 0x04 and then write the command code 0x9c to address 0x00 to cause that value to be transferred to the BMCR.

For example, the host may set BMCR=NAC, and subsequently the BMCR will increment or decrement in lock-step with NAC until the built-in bq27x00 algorithms hold or adjust the NAC value as the battery nears the full or empty conditions. The BMCR continues to increment or decrement according to the charge added or removed from the battery and is not affected by the holding or adjusting that the built-in algorithms make to NAC.

2 Offset Calibration/Compensation

The bq27x00 automatically performs periodic offset calibrations to compensate for offset drift with Vcc and temperature. The BMCR counts are automatically compensated for the measurement offset. The offset compensation is combined with the Board Offset value in EEPROM address 0x7C and is applied to all charge and discharge measurements prior to incrementing or decrementing BMCR. BMCR continues to increment or decrement during the calibration interval using the last measured Vsr signal level prior to beginning the calibration. Offset calibration frequency varies inversely with load current, so any error due to load current changing during the calibration interval is minimized.

3 Digital Magnitude Filter

The DMF threshold setting programmed in EEPROM address 0x7A is automatically applied to all charge and discharge counting. If the measured signal level is less than the programmed DMF threshold, no counting in BMCR occurs. The DMF threshold can be set to zero to disable this function.

4 Self-Discharge Estimate

The bq27x00 contains a variable rate self-discharge count register (SCR) at addresses 0x68 (low byte) and 0x69 (high byte). The count rate of this register varies with temperature in a manner that makes it easy to implement an algorithm to estimate the self-discharge of the battery. The SCR counting is maintained even when the bq27x00 is in a low-power sleep state, such as when the host is turned off or the battery pack is unplugged. When the bq27x00 is used as a monitor, the host has the option of implementing its own self-discharge estimate procedure or of allowing the internal bq27x00 firmware to make the estimate.

Host algorithm: The SCR counts at a rate of 1 count every 87.2 minutes (waking or sleeping) at 25°C. The count rate doubles every 10°C hotter and is halved every 10°C colder. The host can make a fixed percentage reduction of available capacity every time the SCR count reaches some predetermined value. This is an easy way to generate a self-discharge capacity reduction with a rate that is doubled or halved every 10°C. If the value for self-discharge programmed in EEPROM address 0x7A is zero, the bq27x00 firmware will never adjust SCR and the host will have complete control of this function. After the host makes a self-discharge estimate, it should clear the SCR by sending a command of 0x99 to address 0x00.

Gauge algorithm: If a nonzero self-discharge value is programmed in EEPROM address 0x7A, the gauge firmware performs the self-discharge estimate. The self-discharge estimated is proportional to the NAC value determined by the built-in gas gauging algorithms. This same reduction is also made to the BMCR value. It is anticipated that the accuracy of the built-in gas gauging algorithms will provide sufficient accuracy for the self-discharge estimate reduction of the BMCR. That is, if NAC is somewhat close to the host-determined capacity value, calculating the self-discharge estimate as a percentage of NAC will be close enough to use as the self-discharge capacity reduction estimate by the host algorithm. Self-discharge is maintained even when the gauge is sleeping. The gauge periodically wakes up from sleep and applies a self-discharge estimate decrement to NAC and BMCR as required to achieve the programmed rate. It is advisable to program all the EEPROM values as close as possible to appropriate values for the built-in gas gauge algorithms. This allows the best possible measurement of battery capacity possible by the built-in algorithms and yields the best self-discharge estimate.

5 Other Functions Useful to the Host Algorithm

In addition to capacitance, voltage, current, and temperature, the host may elect to use some of the built-in gas gauge algorithms to reduce the computation burden on the host.

Battery Full: The host may elect to use the taper current detection algorithm to determine when the battery is full. If appropriate taper qualification voltage and taper current thresholds are programmed in EEPROM addresses 0x7B and 0x7C, the host can read FLAGS to determine when the bq27x00 sets the IMIN flag (bit 6) to indicate the battery full condition.

Battery Empty: The host may elect to use the EDV1 voltage threshold detection to determine when the battery is empty or almost empty. If a desired EDV1 threshold is programmed in EEPROM address 0x78, the host can read FLAGS to determine when the bq27x00 sets the EDV1 flag (bit 1) to indicate that the battery has been discharged below this threshold. The EDVF voltage threshold programmed in EEPROM address 0x77 can also be used to provide an additional empty condition threshold. The EDVF flag is bit 0

in FLAGS. The bq27x00 never checks for the EDVF threshold until after the EDV1 threshold is detected. The EDV threshold detection requires multiple voltage measurements to prevent a false EDV detection due to a short load transient. The number of measurements varies dynamically with the relative state-of-charge (RSOC) determined by the internal gas gauge algorithms and may take as much as 21.5 seconds with RSOC $\geq$ 6% and as little as 3 seconds with RSOC = 0%.

6   Failsafe

If the host encounters a condition where it determines that its measure of battery capacity is questionable, it has the capability to reinitialize the host capacity computation with the capacity determined by the internal algorithms of the bq27x00. This can be extremely useful if the battery pack has been removed for charging in an external charger or has been removed and is replaced with a different battery pack.

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