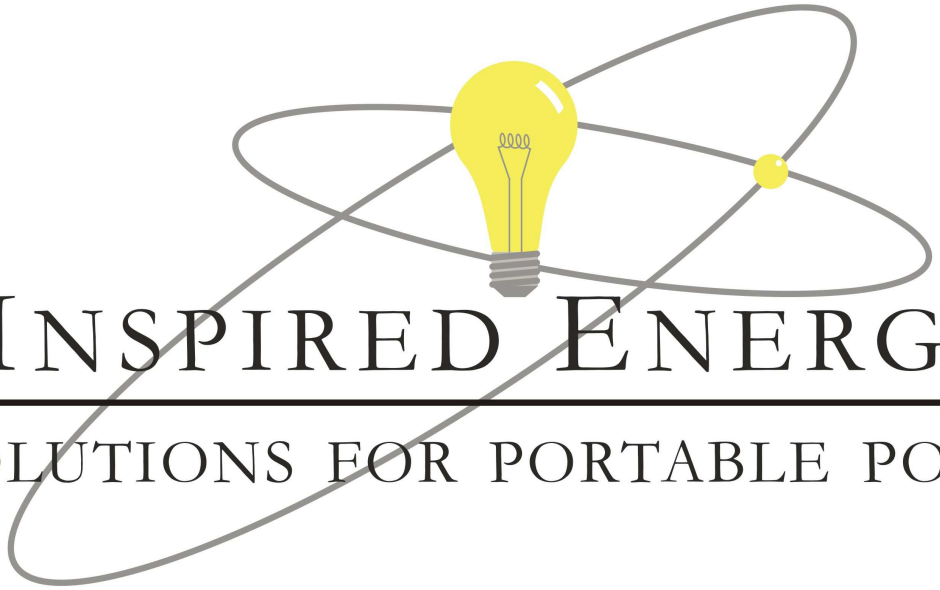


Smart Li Ion Battery User Notes

What is a Smart Li Ion Battery?

Smart batteries are highly sophisticated lithium Ion battery packs designed for use in a variety of applications in which light weight and high energy storage are required. They use the System Management Bus (SMBus) to communicate with the host device and with the charger.

The electronic circuit within the battery has a microprocessor to carry out fuel gauging computations and memory to store key data relating specifically to the lithium ion cells and their associated fuel gauging algorithms.

Charging

Smart batteries should use smart SMBus chargers of level II or higher. The battery will issue commands over the SMBus to the charger in order to control the charge rate and voltage. Upon receipt of the specific charging instructions from the battery, the charger will then configure itself to deliver the appropriate charge. In this way the Smart Battery / Smart Charger system is chemistry & voltage independent. Do not attempt to charge smart batteries with a non-SMBus charger.

Discharging

The runtime of your smart battery will be reduced if it is operated below room temperature. Runtime is not increased by increasing the temperature, but it will reduce the overall life of your battery.

The runtime of your smart battery will be reduced if it is discharged at high currents. (Please refer to the specification document for the maximum continuous discharge current for your battery) Above the maximum discharge current, the safety circuitry will operate (see “Safety” below.) Runtime is not increased by operation at very low currents.

The electronic fuel gauge and protection circuitry in your smart battery are specifically designed to use minimal power, thus leaving the maximum energy available for use by the host device.

Storage

Optimum storage is achieved at room temperature. Elevated temperatures will reduce storage life. Smart Li Ion batteries are shipped with 30 - 50% remaining capacity to give at least 6 months shelf life at room temperature before the electronics go into shutdown mode. It is recommended that the battery is periodically recharged if long storage is required without the electronics going into shutdown mode.

Lithium ion cells must not be over-discharged (see “Safety” below). For this reason the electronics in your smart battery have three states of power consumption.

1. Active - the battery is operational and the electronics are actively monitoring and communicating battery status.
2. Sleep - the battery has not been used for a few seconds.
3. Shutdown - the battery is in storage and has self discharged down to a pre-set voltage. At this point the electronics self-disconnect removing their electronic load from the cells. This provides approximately 1 year of room temperature storage before the cells self discharge to the point beyond which they should not be recharged.

After a period of shutdown, the battery will undergo a self-test immediately upon being put charge. The electronics will “wake-up” and begin to monitor battery voltage in response to a very low initial charge rate which is delivered by the SMBus charger. If the voltage does not recover then the battery pack has been allowed to discharge beyond the point of safe recovery. The charge will be terminated and the battery pack should be replaced.

During electronic shutdown, the volatile parts of the memory may have been lost and the SMBus register may need to re-create these during the next few cycles. Until this is completed, fuel gauge

accuracy will be reduced. Carrying out a recalibration cycle as soon as possible after shutdown can speed up this process.

During electronic shutdown no SMBus data critical to the safe operation of the smart battery is lost.

Recalibration

"Real-life" applications rarely fully discharge a battery pack. Frequent partial discharges are not a problem to your smart battery, however after repeated use in this way, the accuracy of the fuel gauge may be reduced.
The smart battery has a built-in monitoring system which checks the accuracy of the fuel gauge, based on the discharge history of the battery. This is broadcast over the SMBus and can be used by the host device to inform the user when to recalibrate the electronic fuel gauge.

Recalibration of the electronics is achieved by fully recharging the battery followed by a full discharge. Depending on the storage history of the battery pack, the smart battery may require calibration from new.

Life

End of life for a Li Ion smart battery is defined as the point at which the battery fails to deliver 80% of its original rated capacity. The end of life which is acceptable in your application may differ from this industry definition.
The smart battery is designed to provide 300 full charge/discharge cycles at room temperature and under normal discharge rates. Cycle life will be maximized by using the end of discharge instructions issued by the smart battery to the host device over the SMBus. Use of a fixed voltage cutoff by the host device may reduce the cycle life of the product because although the battery may have available capacity remaining it may be at a voltage which is below the device voltage cutoff. If the smart battery is not fully discharged each time, the number of cycles available over life will increase.

The Fuel Gauge

Your smart battery employs either a 5 segment LCD fuel gauge that is always active unless the battery is in shutdown mode, or a 4-segment LED fuel gauge which is activated by a pushbutton.

For LCD fuel gauges:

- Between 81 and 100% charge, all 5 LCD segments will be filled
- Between 61 and 80% charge, 4 LCD segments will be filled
- Between 41 and 60% charge, 3 LCD segments will be filled
- Between 21 and 40% charge, 2 LCD segments will be filled
- Between 1 and 20% charge, 1 LCD segment will be filled

For LED fuel Gauges:

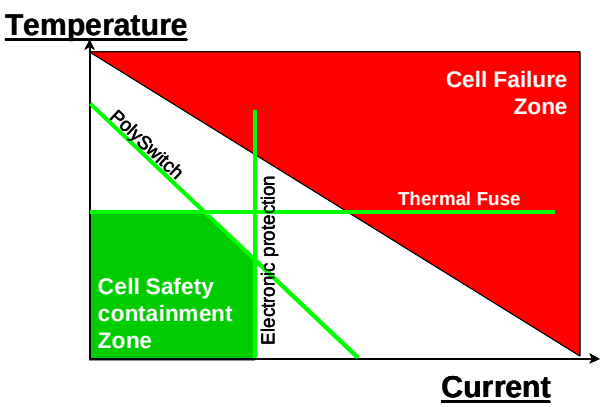
- Between 76 & 100% charge all four LED's will light
- Between 51 & 75% charge 3 LED's will light
- Between 26 & 50% charge 2 LED's will light
- Between 10 & 25% charge 1 LED will light
- Below 10% charge, one LED will flash

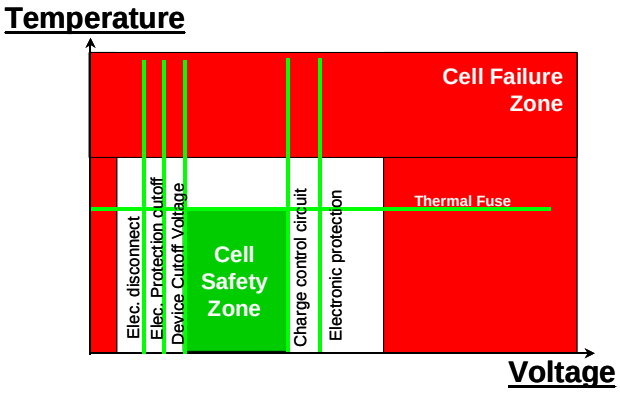
Below 1% charge, there will be no fuel gauge indication & fuel gauge accuracy in normal use is typically ±1.5%.
The smart battery continuously monitors the accuracy of its on-board fuel gauge and broadcasts its accuracy level over the SMBus. This information can be used by the host device to inform the user if there is a need to recalibrate the electronic fuel gauging system.

Safety

Lithium Ion cells contain a tremendous amount of stored energy. They require protection to ensure that this energy is always delivered in a controlled manner. The smart battery features passive and active electronics with multiple levels of redundancy to ensure that the battery remains safe in all failure modes. The two sketches below illustrate the response of lithium ion cells to varying temperature, current and voltage, and demonstrate how the multiple levels of protection devices function to ensure that the cells remain within the safety containment zone at all times.

Excessive temperatures will cause cell failure. Smart batteries feature devices which will prevent further charge or discharge if exposed to high temperatures. This protection device will re-set when the temperature is lowered. There is also a thermal fuse, which will permanently shut down the battery if it is exposed to excessive temperatures.





Lithium Ion cells can be damaged by excessive current flow either in charging or in discharging. The electronic protection circuit senses current flow in and out of the battery. If excessive currents are sensed, the protection circuit will open a switch in either the charge circuit or the discharge circuit to prevent further current flow in that direction. Additional passive safety devices will act to prevent further charge or discharge if excessive currents or temperatures are sensed.

Lithium ion cells require strict voltage control during charge and discharge. During charging the smart battery will control the SMBus charger to ensure that the charging voltage is not exceeded. If the battery continues to receive excessive charge voltage, the electronic protection system will open the charge circuit to prevent further charging. When the source of excessive voltage is removed, normal charging can resume. During discharge the device should be designed to shut off at a safe, predetermined voltage. Inspired Energy recommends that the device uses the SMBus end of discharge alarms issued by the smart battery to gain maximum runtime over the life of the battery pack without impacting safety. If the device continues to discharge the battery beyond the cutoff voltage, the electronic protection system will disconnect the discharge circuit and prevent further discharge. If discharge continues, the electronics enter shutdown mode (See “Storage” above) to prevent over discharge of the cells.

The electronic protection system is completely independent of the SMBus and fuel gauge. This ensures that the electronic protection is not disabled in the case of a problem with the fuel gauge or communications system.

The SMBus

The smart battery communicates 34 separate pieces of battery status data to the host device and/or charger over the SMBus. How many of these are used and how effectively they are employed depends on the host device design.

The smart battery has an on-board meter to measure current and voltage in and out of the battery at a resolution of <1mV and <0.5mA for the on-board fuel gauge. Temperature is monitored to within ±3°C.

Some of the information provided by the smart battery which can be transmitted over the SMBus & which may be useful to a device user is listed below:

1. Remaining time to empty – a measure of how much runtime remains based on the current discharge rate (in minutes)
2. Remaining time to full – a measure of how long the battery will take to reach full charge
3. Cycle count – how many charge and discharge cycles the battery has undergone
4. Remaining time alarm – this can be set by the host device to give the user a warning at a predetermined point before the device shuts down (eg "you have 5 minutes of runtime remaining)
5. Max error – a measure of how accurately (or inaccurately) the fuel gauge is currently operating. This can be used by the device to notify the user to recalibrate the battery pack.

Although this information is broadcasted to the host device and the charger, your device may not have the capability to transmit these messages from the battery to you.

A handheld SMBus reader is available by special order from Inspired Energy, Inc. this allows a user to interrogate the battery and immediately view the battery status.

The host device or charger may not be designed to listen to or act upon the instructions issued by the smart battery. As a minimum, for optimum operation, Inspired Energy recommends that the following SMBus commands from the battery are used by the device and charger:

1) The "Terminate Discharge Alarm" and/or "Fully Discharged" bit. This will provide the user with maximum runtime and cycle life throughout the life of the product and to ensure proper calibration cycles are achieved.
2) The "Terminate Charge Alarm" and/or "Fully Charged" bit to maximize capacity, ensure correct, full charging and to ensure proper calibration cycles are achieved.
3) The "Max Error" value to signal to the user when a recalibration is required.
4) The Remaining Time To Empty value should be employed to give the user an accurate update on remaining runtime. This is a much more useful value to the end user than the percentage of remaining capacity.

Smart Battery Specifications

For a detailed engineering specification, including details of the SMBus communication system, engineering data sheets for all Inspired Energy smart batteries are available to download from www.inspiredenergy.com.