The NI2020 Smart Battery
User Notes

What is the NI2020 Smart Battery?

The NI2020 is a highly sophisticated 10.8V lithium Ion battery pack designed for use in a variety of applications in which light weight & high energy storage are required. It uses the System Management Bus (SMBus) to communicate with its host device and with its charger.
The NI2020 uses Electronically Programmable Read Only Memory (EPROM) to store key data relating specifically to the particular lithium ion cells used and their associated fuel gauging algorithms. This is a preferable solution to an Application Specific Integrated Circuit (ASIC), which gives a generic, approximated solution aimed at covering all lithium ion cell types. The NI2020 programming can readily be updated to accommodate cell upgrades, performance changes or to include some custom features required by customers. Please contact Inspired Energy, Inc. for details on custom hybrid versions of the NI2020.

Charging

The NI2020 requires a smart SMBus charger of level II or higher. The battery will issue commands over the SMBus to the charger in order to control the charge rate & voltage. Do not attempt to charge the NI2020 with a non-SMBus charger.

Discharging

The runtime of your NI2020 will be reduced if it is operated below room temperature. Increasing the temperature does not increase runtime, but it will reduce the overall life of your battery.
The runtime of your NI2020 will be reduced if it is discharged at high currents. (The NI2020 can deliver a maximum of 3A continuously) Above certain currents the safety circuitry will operate (see “Safety” below.) Runtime is not increased by operation at very low currents.
The electronic fuel gauge & protection circuitry in your NI2020 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.
NI2020 batteries are shipped with a minimum of 20% 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 NI2020 have three states of power consumption.

1. Active - the battery is operational & 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 requested by the battery of 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 will have been lost & the SMBus register will 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 NI2020 is lost.

Recalibration

"Real-life" applications rarely fully discharge a battery pack. Frequent partial discharges are not a problem to your NI2020, however after repeated use in this way, the accuracy of the fuel gauge will be reduced.
The NI2020 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 discharging any remaining capacity in the NI2020, a full recharging followed by a full discharge. Depending on the storage history of the battery pack, the NI2020 may require calibration from new.

Life

The NI2020 is designed to provide 300 full charge/discharge cycles at room temperature & under normal discharge rates. Cycle life will be maximized by using the "Dynamic End of Discharge" shutdown system (Patent pending) & the end of discharge instructions issued by the NI2020 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. If the NI2020 is not fully discharged each time, the number of cycles available over life may increase.

The LED Fuel Gauge

The NI2020 employs a 4 segment LED fuel gauge, activated by a push button.
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
Fuel gauge accuracy in normal use is typically ±1.5%
The NI2020 continuously monitors the accuracy of its on-board fuel gauge & broadcasts it's accuracy level over the SMBus. The host device can use this information 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 NI2020 features passive and active electronics with multiple levels of redundancy to ensure that the battery remains safe in all failure modes.

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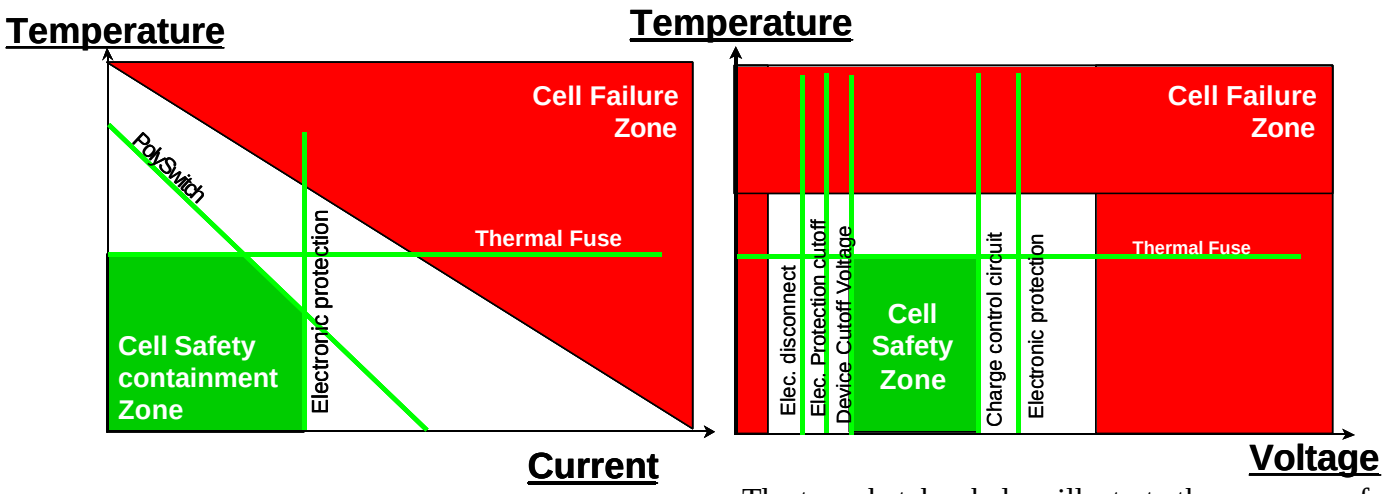

The two sketches below illustrate the response of lithium ion cells to varying temperature, current and voltage, and demonstrate how the multiple levels of protection devices function to ensure that the cells remain within the safety containment zone at all times.

Excessive temperatures will cause cell failure. The NI2020 features a Polyswitch™ device which will introduce a very high resistance into the circuit & 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 & 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. The Polyswitch ™ device responds to both current and temperature & if excessive currents are passed, it will introduce a very high resistance into the circuit to prevent further charge or discharge. (Polyswitch™ is a trademark of Raychem corp.)

Lithium ion cells require strict voltage control during charge & discharge. During charging the NI2020 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 NI2020 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 & prevent further discharge. If this system is defeated and discharge continues, the electronics will disconnect the battery and enter shutdown mode (See “Storage” above) to prevent over discharge of the cells.
The electronic protection system is completely independent of the SMBus & fuel gauge. This ensures that the electronic protection is not disabled in the case of a problem with the fuel gauge or communications system.

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The SMBus

The NI2020 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 NI2020 uses 16 bit sampling to measure current & voltage in & out of the battery. This achieves a resolution of <1mV & <0.5mA for the on-board fuel gauge. Temperature is monitored to within ±3°C.

The NI2020 monitors the normal voltage decay over life of its lithium ion cells & can change its end-point voltage to ensure maximum dischargeable capacity is available throughout the battery's life. This feature is unique and is referred to as "Dynamic End Of Discharge Voltage". Use of this feature by the host device will ensure maximum runtime and cycle life for the battery.

If the "Dynamic End of Discharge Voltage" communicated by the battery over the SMBus is not used, the battery should use an 8.1V cutoff voltage; runtime and cycle life may be reduced.

The NI2020 broadcasts its status over the SMBus. Some of the information provided by the NI2020, which may be useful to a device user, is listed below:

1. Remaining time to empty – a measure of remaining runtime based on the current discharge rate
2. Remaining time to full – a measure of how long the battery will take to reach full charge
3. Cycle count – how many charge & 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. The host device can use this to notify the user of the need to recalibrate the battery pack electronics.

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 NI2020. As a minimum, for optimum operation, Inspired Energy recommends that the following SMBus commands from the battery are used by the device & charger:

1) The "Terminate Discharge Alarm" &/or "Fully Discharged" bit. This will ensure that the End Of Discharge Voltage (EODV) is used to provide the user with maximum runtime and cycle life throughout the life of the product & to ensure proper calibration cycles are achieved.
2) The "Terminate Charge Alarm" &/or "Fully Charged" bit to maximize capacity, ensure correct, full charging & 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.

NI2020 Specifications

A detailed engineering specification, including details of the SMBus communication system, is available at www.inspired-energy.com.