A123 Systems, Inc.
Arsenal on the Charles
One Kingsbury Ave
Watertown, MA 02472

Battery Pack Design Safety Guidelines (DRAFT)

While we believe the A123Systems' Nanophosphate™ cells are the safest lithium ion cells on the market, there remain ways, including improper use or abuse, to make our cells fail, which can lead to potential safety hazards to the end user. Packs must therefore be designed in accordance with the customary parameters of battery pack design to avoid a safety incident:

Guidelines for safe cell protection and battery design:

- Pack must have dual, redundant over-voltage protection, with at least protection by hardware and one via software.
- The voltage of every single series element must be measured and monitored.
- In multi-cell batteries, use cell balancing and/or individual cell voltage controls to equalize the state of charge (voltage at full charge) of cells in series. Doing this will also maximize the life of the system.
- Cells discharged below 0.50V will be damaged and must be removed and properly disposed.
- Recommended and Absolute ANR 26650 Cell Limitations:

	Recommended	**Absolute**
Maximum cell voltage	3.85 volts	4.20 volts
Minimum cell voltage	1.60 volts	0.50 volts
Maximum continuous recharge current		10 amps
Maximum continuous discharge current		70 amps
Maximum 10 second pulse recharge (at Room Temperature)		10 C rate
Maximum 10 second pulse discharge		120 amps
Maximum temperature difference between cells in a pack	< 5°C	8°C

- Maximum charge and discharge current ratings are at STP (standard temperature and pressure); at different temperatures, especially lower temperatures, maximum current rates will be lower.

- Cells must not be subject to reverse polarity or short circuited. Fuses or some other protection must be incorporated in pack designs with batteries in parallel to avoid all the energy in one string being dumped to the neighboring batteries in the event of a hard short cell failure.
- Cells must not be charged or discharged outside the operating temperature range in the datasheet, and reduced charging limits must be followed for lower operating temperatures.
- Cells must not be exposed to heat in excess of 60°C during operation, 70°C in storage; or incinerated, stored or used near open flames.
- Cells must not be punctured, ruptured, dented or crushed; and the pack design must ensure this under normal operations or in a crash.
- Cell packaging must not be altered in any way, and cells must not be immersed or exposed to water or liquids
- Tabs should be resistance or laser welded to cells to avoid excessive heat. When leads are soldered to the cells, the cell casing must not exceed 150°C for more than 10 seconds.
- Never use a clamping force at the top and bottom of the cell or hold cells together, end to end, in a way that restricts the cell rupture vents at the ends of the cells. If the vents are blocked, the gas can't exit the cell in case of cell failure.
- **Overall: Cell specifications in the datasheets must be followed. Cells must be balanced during recharge for long life and safety, and individually monitored and protected from exceeding specified operating parameters. Battery packs must be designed and confirmed via testing to provide sufficient mechanical, thermal and electrical protection to keep each individual cell within proper operating limits. Do not ship product before thoroughly testing a pack design.**

In automotive or EV solutions we recommend that your pack abides by these general guidelines and makes use of the following components:

- All high voltage components, including wires, cables, connectors, and batteries with a potential greater than 54 volts must be colored orange.
- Crash sensor signal to disconnect the battery pack from the vehicle.
- Reliable and validated mechanical design that meets SAE J2464 & J2380 standards.
- National Highway Traffic Safety Administration, DOT, Part 571 – Federal Motor Vehicle Safety Standards, Standard No. 305; Electric-powered vehicles:

electrolyte spillage and electrical shock protection, and other FMVSS standard(s) that govern PHEV or crash testing

- Appropriate mechanical vibration tests to ensure the pack will meet the applicable environmental requirements.
- Mechanical mounting should prevent mechanical stressing of seals and joints on the cell. Mechanical design should also prevent deformation of the cell under all conditions.
- System components should be compatible with cell electrolyte solvent, in case a cell is vented and the electrolyte leaks.
- Battery cases and mounting hardware should be protected or made of appropriately rated dielectric material to prevent accidental shorting to chassis.
- All high voltage connections should be robustly isolated and protected from contacting adjacent components to prevent shorting during severe mechanical abuse (crash, crush, impacts, etc).
- Battery systems should be designed that it should be impossible to drop a tool into the pack and cause a short circuit. No high voltage should be accessible with an average finger.
- Batteries and battery packs should be fused. One fuse should be located in the center of the battery system to break the load at the center of the pack.
- Battery packs should use contactors capable of breaking full current loads on both the positive and negative poles of the battery pack. These contactors should be normally open contactors such that if supply power is stopped, they will open.
- Battery packs should include a HVIL (High Voltage Inter Lock) that supplies power to the main contactors. This loop should also run through switches that ensure that the housing is closed, the crash sensor (if included) is closed, and the high voltage power connector, low voltage communications connector, and other key interfaces are in place. In the event that any one of these opens, the contactors will open.
- Current conductors and connections should be of sufficiently low impedance to prevent localized heating of surfaces and components.
- A battery pack should be equipped with a battery management system to operate the pack properly and to shut down the pack in case of internal or external abusive conditions. The battery management system should provide the following:
    - Minimum and maximum voltage limits should be included in the algorithms to prevent abuse from overcharge and overdischarge.

A123 Systems, Inc.
Arsenal on the Charles
One Kingsbury Ave
Watertown, MA 02472

- Temperature sensors should monitor system and cell temperatures throughout the system for both safety and algorithm purposes.
- The battery management system must be able to monitor each series element voltage.

- Temperature can act as a redundant check against overcharge, short circuit, and over discharge conditions that are not reported due to an error in voltage measurement. Both Tmax and dT/dt limits should be considered to prevent abuse of the cells.

- Monitoring the SOC of the cells is necessary to ensure a long life battery, but also should act as a secondary detection of overcharge and overdischarge conditions. Max SOC and min SOC limits should be set in the algorithm to prevent abuse.

- State of Health software algorithms should be implemented to detect weakening cells during operation. Examples of this are a cell being the highest voltage cell on charge and the lowest voltage cell on subsequent discharge. This is an indication that the cell is becoming resistive and should trigger a service condition.

- The customer further acknowledges that the following potential consequences may occur if the cells are subjected to misuse or abuse:
  - Cell may vent and will become inoperable
  - Cell life will be degraded
  - Cell performance to datasheet specifications will be degraded
  - Cell may cause burns due to excessive heating

A123 is providing this information based on its current knowledge of best practices in battery pack design in order to raise your awareness on appropriate cell use so that immediate corrective action can be taken if your firm is employing a pack design that can potentially cause safety problems.

A123 shall have no liability with respect to its products or any failure of its products to perform in accordance with their specifications or in accordance with any applicable warranty if such performance or failure results, either in whole or in part, from any use that is inconsistent with the above recommended Guidelines or any changes or modifications to the products that are not made by A123 or authorized in writing by A123. In such event, you will be solely responsible for the consequences of any noncompliance. In addition, A123 makes no warranties, either express or implied, regarding the contents of this letter or the completeness or accuracy of the guidelines and best practices described herein, which is provided for informational purposes only.