
# Battery Handling Guidelines

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**Product Quality Engineering**

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*Note: The information contained in this document is for reference only. It should not be used in place of appropriate Federal, State, or local regulations or other legal requirements. A123 Systems is not responsible for updating the contents of this document or for any incident that occurs due to misuse or abuse of lithium cells and/or batteries.*

# Battery Handling Guidelines

## Foreword

A123 Systems is a leading global manufacturer of advanced high power, safe and long-life lithium-ion energy storage solutions for next-generation applications in the transportation, electric grid and commercial markets. The purpose of this document is to provide guidance related to the storage and handling of A123 Systems' batteries in both normal and emergency conditions. Under certain circumstances, lithium ion cells can produce unintended electrical discharge, overheat, and/or vent, potentially causing harm to nearby personnel and property. Care should be used in storage, handling and shipping. These guidelines outline the typical conditions under which hazards may arise, and general precautions for safe handling.

These guidelines contain recommendations on the safe and proper handling of lithium ion batteries. The end user is responsible for complying with each region's differing requirements or regulations. **It is the responsibility of each end user to establish their own internal policies and procedures while adhering to all applicable local regulations**. These guidelines are not intended to provide all the information that you will need, but instead to help facilitate your development of site-specific policies and procedures.

A123 is a provider of lithium ion battery cells, modules, and packs – this document is not specific to a particular item type but written generically to apply to any of these. The primary focus is on vehicle applications, but caring for the base lithium ion cell is at the core of the recommendations, and the same cells are also used in non-vehicle applications as well. Each end user should tailor their procedures to their specific applications that employ the use of these batteries. For end-user customized applications of cylindrical cells, please also refer to design guidelines posted in the A123 website resources section, www.a123systems.com/resources.

## Main Topics *(hyperlinked)*




## Section Topic

# Introduction: Lithium Ion Battery Basics

**Other Topics:** *(hyperlinked)*



# Battery Handling Guidelines

## Introduction: Lithium Ion Battery Basics

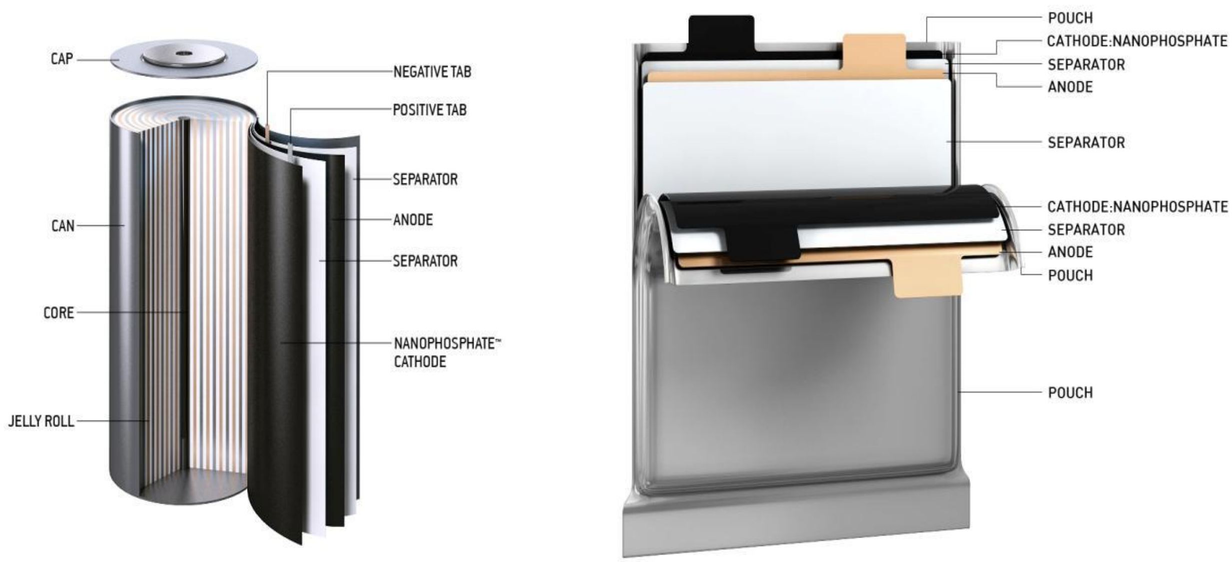
### A123 Terminology

- **Cell**: the smallest unit energy storage device; where the chemical reaction occurs.
- **Cell Group**: a number of individual cells wired together in parallel; to increase capacity.
- **Module**: a number of cells grouped together as a replaceable unit; along with electronic module controls. Modules can contain individual cells or cell groups wired in series.
- **Pack**: a number modules wired in-series, grouped together as a unit along with electronic pack controls.
- **Battery**: generically used, can be referring to any one of the above-listed items.

### Cells

The heart of all A123 battery systems is the **lithium ion cell**. The cell is where the chemical reaction occurs when ions are transferred between anodes and cathodes and the associated movement of electrons produces electrical current. Cells have two forms – cylindrical or prismatic, shown below. Either form contains the same basic ingredients – a set of anodes and cathodes with an electrically insulating separator between each, contained in a can or pouch along with an electrolyte solution that allows for transfer of ions.

**Cylindrical and Prismatic Form Factors:**




A123 cells are made with a lithium iron phosphate chemistry, which is generally considered to be safer than the lithium metal oxide chemistries used by other manufacturers. There is no metallic lithium in the cells, so there is no chemical reactivity with water. The cells have a nominal voltage of 3.3V (volts), and are generally considered to have working thresholds being fully charged at 3.6V and fully discharged at 2.5V. Capacities vary based on form factors.

# Battery Handling Guidelines

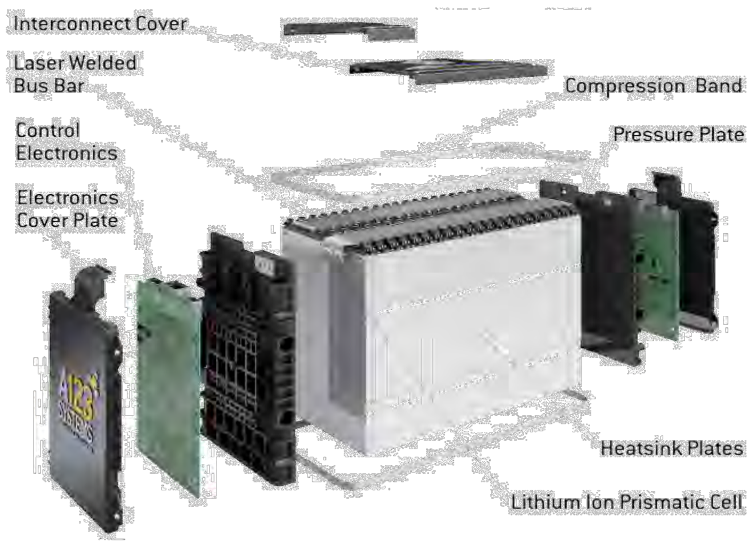
## Introduction, continued

### Modules

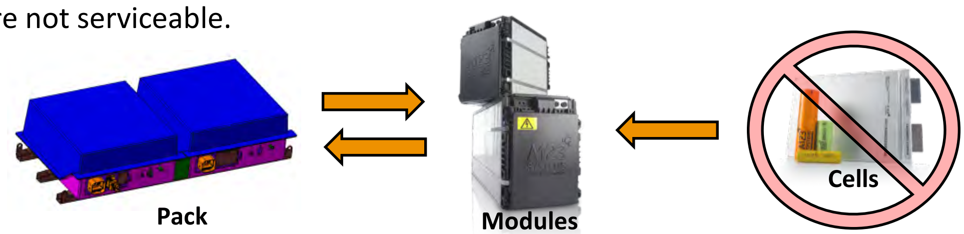
Battery **modules** are combinations of lithium ion cells connected in-series to increase voltage and/or in-parallel to increase capacity. Multiple combinations are possible depending upon the application needs. Modules also contain electronic controls to monitor temperature and cell group voltages; and to balance cell group voltages using resistors to bleed voltage from the higher voltage cell groups. This happens on a monitoring and balancing board (MBB), attached to the module. Module MBB's communicate with system controllers via an internal low-voltage (LV) CAN-based network.

**Cylindrical Cell Modules:**

**Prismatic Cell Modules:**




Modules are designed to be removed and/or replaced from packs for service. Replacement of module MBB(s) is a serviceable item. Do not disassemble modules, as individual cells within A123 modules are not serviceable.



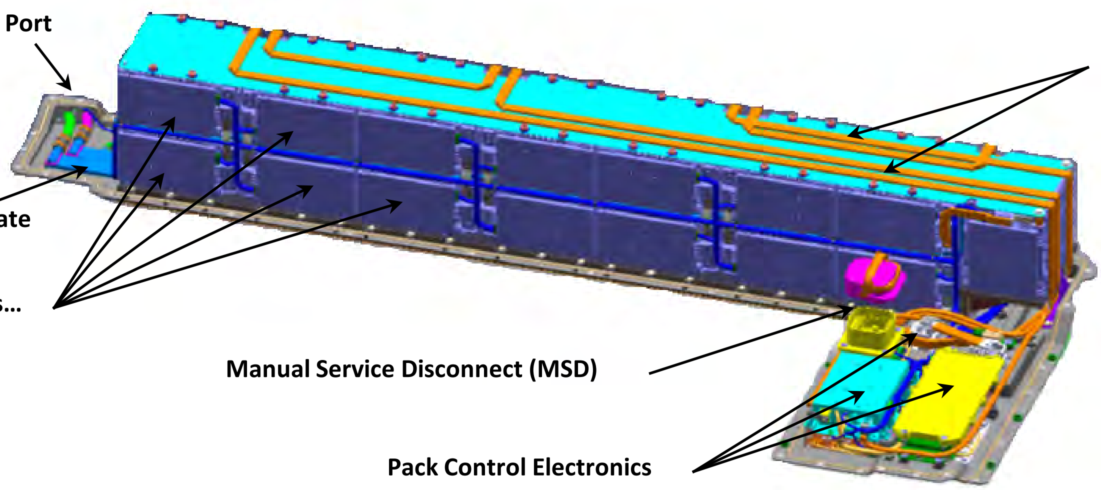

  

# Battery Handling Guidelines

## Introduction, continued

### Packs

Battery **packs** consist of a number of modules wired in series with each other, contained in an enclosure that also includes electronic controls. Packs can be various of sizes, shapes and electrical properties, and are designed with the specific application in mind. They may include either liquid or air cooling to manage module temperatures. Bus bars are used to electrically connect the modules, and a manual service disconnect is usually integrated into the pack to provide mechanical ability to interrupt the series circuit of modules and prevent the flow of current.

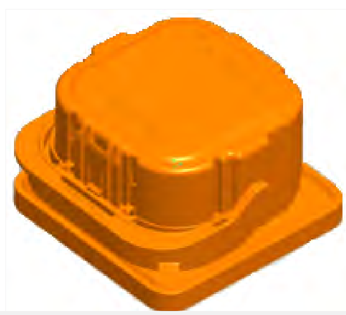



### Pack Safety

All packs have as a safety mechanism a wiring loop called the **High Voltage Interlock Loop (HVIL)**.

The principle of the HVIL is to use a low-voltage current loop that protects against access to the devices which contain high-voltage. Interruption of that ring circuit at any position (e.g. fuse panel removal) leads to deactivation of the high voltage (HV) by opening the HV contactors. The HVIL is voltage-controlled and it is pulsed to allow for loop diagnostics.

The **Manual Service Disconnect** (**MSD**) is used to manually deactivate the current flow to the pack connections. It is a manually operated two-stage device that first interrupts the HVIL to stop current flow to outside the pack; and then opens the HV wiring connection so the pack internal voltage is cut in half. Some MSD's will also contain a HV fuse integral to the device that will interrupt HV current when blown.



Manual Service Disconnect

**Always disconnect and remove the MSD before doing any service work on the pack.**

In addition, safe pack operation is ensured through electronic modules integrated into its design. Those electronic modules are described on the next page.

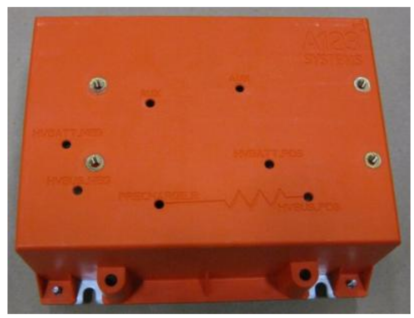
## Introduction, continued

### Pack Electronic Modules

Electronic controls are necessary to manage the inflow and outflow of electricity, monitor current, and communicate with the vehicle/charger/external controller. These controls are necessary for the safe operation of the pack, as they determine if the pack is operating within specified parameters and report trouble codes if there is a problem. They also provide for emergency power off if the problem is potentially serious.

Primary electronic control modules include the following:

+ **EDM: Electrical Distribution Module** – A system of contactors that provide HV relayed connection between the battery pack and the vehicle. An EDM provides a base for mounting a variety of contactors used for positive and negative HV connections, charger leads and auxiliary equipment. It also usually includes a precharge resistor, current sensor and interface connector.



+ **CSM: Current Sense Module** - Sensor that monitors input and output current of the high voltage bus circuits. The CSM communicates with the Battery Control Module (BCM) on a low-voltage internal pack CAN bus, performing the following functions:

  + Makes and reports high voltage measurements to the BCM,
  + Reports faults to the BCM,
  + Monitors isolation between the HV and LV systems,
  + Provides a real time clock powered by the HV system, and
  + Provides a heartbeat function on the internal LV bus for timing.

+ **BCM: Battery Control Module** –
This is the LV master controller of the battery pack, and provides the internal CAN communication between controllers and external communication to the vehicle. It stores the application software, monitors operating conditions, reports faults, and manages contactors.

Electronic control modules in all packs are designed to be replaceable, each as a complete unit (with the exception of starter batteries, which have no replaceable components).

# Battery Handling Guidelines

## Introduction, continued

### Basic Electrical Summary on the Cells in Modules and Packs

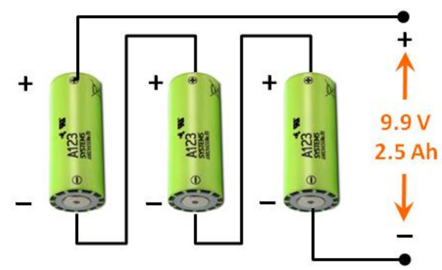
Understanding the basics of how cells are combined into modules and packs is useful for battery safety and servicing. In the table below are some guidance-only electrical data for single cells using A123 chemistry. Please refer to the Resources section of A123 Systems website for cell data sheets.

| Cell Type | Characteristic | Value |
|---|---|---|
| All A123 Nanophosphate© Cells | Nominal Voltage | 3.3 V |
| | Operating range: Fully Charged | 3.6 V |
| | Operating range: Fully Discharged | 2.5 V |
| | Maximum V during charge w/o damage to cell | 3.7 V |
| | Minimum V at rest w/o damage to cell | 1.0 V |
| 26650 Cylindrical | Nominal Capacity (Amp Hours) | 2.5 Ah |
| 32113 Cylindrical | Nominal Capacity (Amp Hours) | 4.5 Ah |
| AMP20 Prismatic | Nominal Capacity (Amp Hours) | 20 Ah |

**Note:** Please refer to application-specific specifications for battery charging information. Significant hazards exist if batteries are overcharged beyond maximum voltages.

Cells are connected in **series** to achieve higher operating voltages for the specific application need. For cells or groups of cells connected in series, the voltages are additive.

They can also be connected in **parallel** to achieve higher power and/or energy. Cells connected in parallel produce the same voltage as a single cell, but the capacity of the cell group is the sum of the cell capacities.

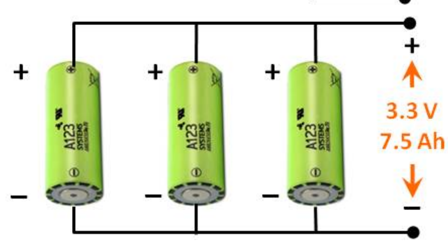



Cells in **SERIES:**

Each cell is 3.3 V; 2.5 Ah

3.3V +3.3V +3.3V = **9.9 V**

Total Capacity = **2.5 Ah**



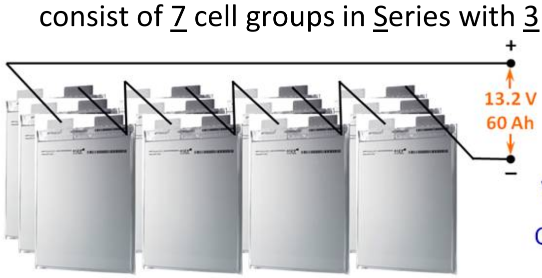

Cells in **PARALLEL:**

Each cell is 3.3V; 2.5 Ah

Total Voltage = **3.3 V**

2.5Ah+2.5Ah+2.5Ah = **7.5 Ah**

Modules are designed to put enough cells in parallel to have the capacity needed for the application. Cells connected in parallel with each other are called cell groups. A module will have a number of cell groups connected in series to increase its voltage, and will be designated with an acronym describing the number of cells in series and parallel. For example, a 7S3P module would consist of 7 cell groups in Series with 3 cells in Parallel per group, for a total of 21 cells.




12 Prismatic Cells in **4S3P Configuration:**

Each cell is 3.3V; 20 Ah

Voltage = 4 x 3.3V = **13.2 V**

Capacity = 3 x 20Ah = **60 Ah**

**4S3P: 4** cell groups in **S**eries with **3** cells in **P**arallel in each group

Packs typically have several modules wired in series. Pack voltage is the sum of the module voltages, and capacity is the capacity of a cell group. Modules wired in series generally wire the MSD in the middle of the series, which cuts total internal pack voltage in half when open.

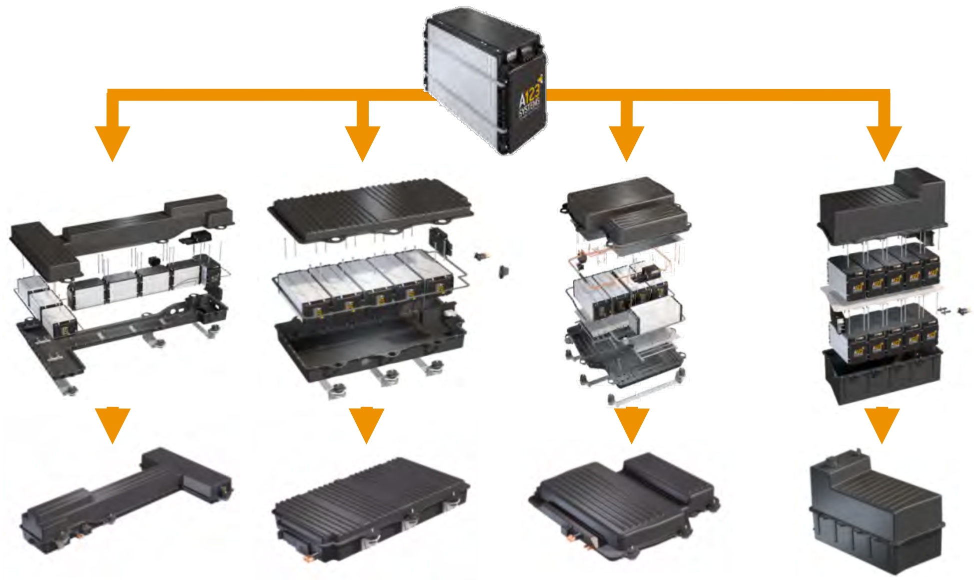
# Battery Handling Guidelines

## Introduction, continued

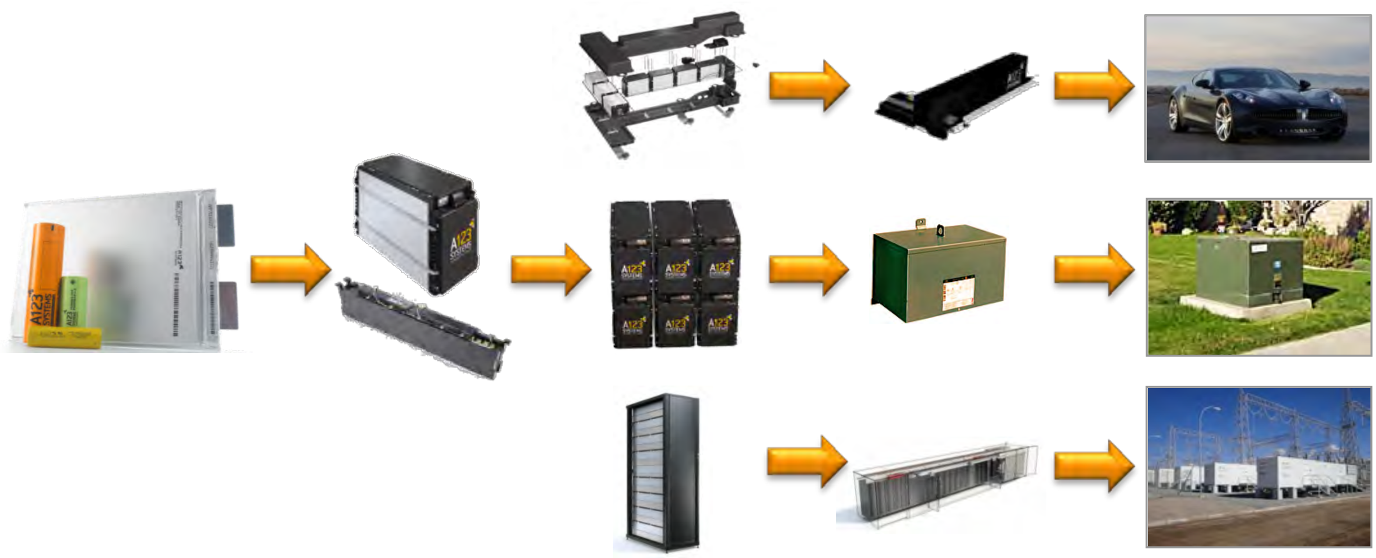
### Modular Building Block Architecture for a Variety of Applications

Packs can be configured in a variety of shapes and sizes depending upon the space constraints of the vehicle they are designed for. On the right are some illustrations of various pack shapes.

The same components that make a vehicle-oriented pack can be used for electric grid and other applications where high voltage energy storage is required.



**Cells -> Modules -> Packs**



### Handling Guidelines

The following pages of guidelines for safely handling, storing, maintaining, shipping and recycling along with emergency response procedures are all based on protections desired for the **base unit of each type of battery system – the lithium ion cells**.