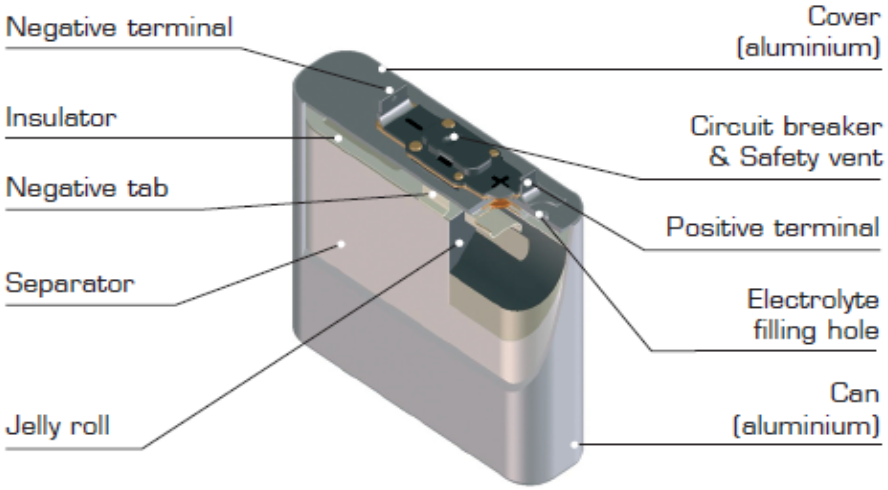
Li-Ion Battery Design

International Distribution Seminar

April 2014

Saft MP176065 INT Design



Built-in protection devices ensure safety in case of:

- Exposure to heat
- Exposure to direct sunlight for extended periods of time
- Short circuit
- Overcharge
- Overdischarge

Safety : high level via redundant features

- Level one : fail safe charging device
  > **limited current and voltage**
- Level two : protection circuit (able to re-set)
- Level three : mechanical current breaker + thermal fuse
- Level four : 3 - layers separator (shut down)
- Level five : mechanical rupture disk (burst vent)

Protection Circuit

- Customized to Each Battery Pack but based on standards
- Monitor cells and opens circuit if it detects:
  - > **Over Voltage above 4.25 V on any Cell**
  - > **Over Discharge below 2.5V on any Cell**
  - > **Over- charge current (irreversible)**
  - > **Over-discharge current**
  - > **Short circuit**
  - > **Enters sleep mode at low voltage (any cell)**

Current Breaker and Burst Vent

- Current breaker physically opens circuit at 4 to 9 Bars Pressure
  - > **Cannot be Reset**

- Burst vent opens at 11 to 12 bars of pressure
  - > **Cannot be Reset**

MP and D cells performances

Protection Circuit

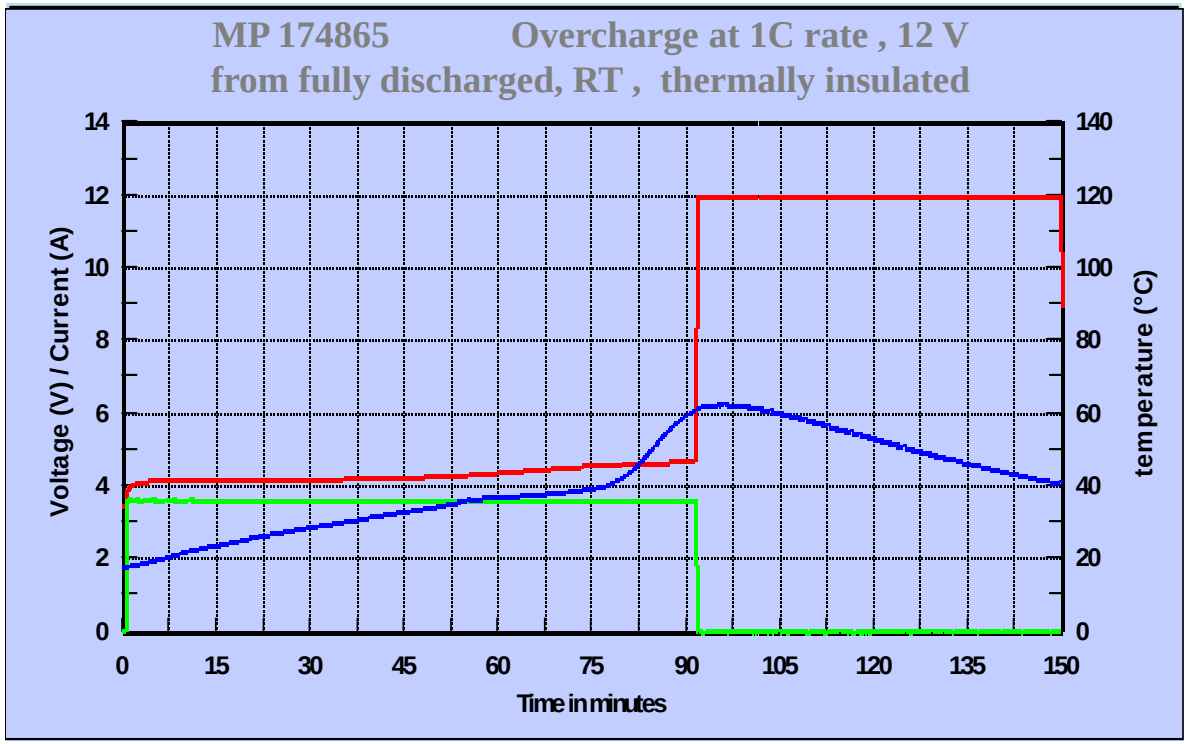
- Customized to Each Battery Pack but based on appropriate values
- Monitor cells and opens circuit if it detects:
  - > **Over Voltage above 4.25 V on any Cell**
  - > **Over Discharge below 2.5V on any Cell**
  - > **Over- charge current (irreversible)**
  - > **Over-discharge current**
  - > **Short circuit**
  - > **Enters sleep mode at low voltage (any cell)**

Three Layer Separator

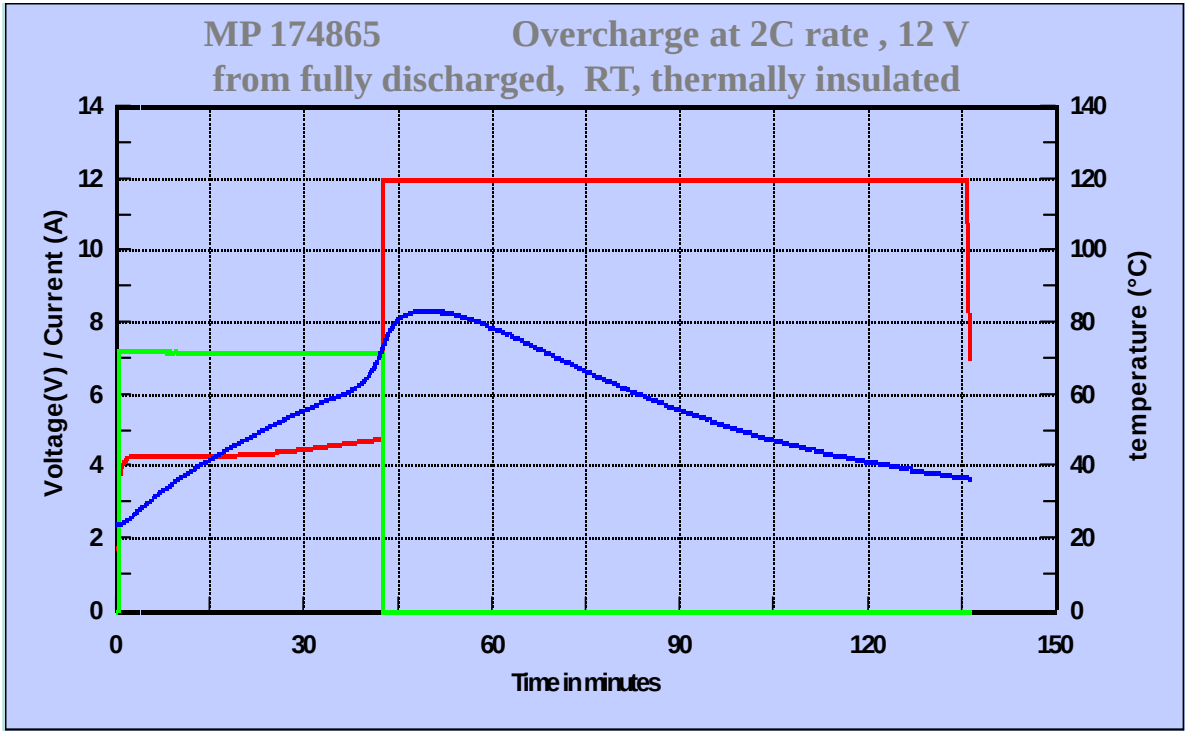
- Polyethylene layer: melts at 130 °C
  - > **Shuts off all electrochemical activity**
- Polypropylene layer: melts at 165 °C
  - > **maintains a rigid structure between electrodes**
- Laminated PP / PE / PP combines both
  - > **Shutdown feature with polyethylene**
  - > **Mechanical Integrity with polypropylene**

- Thickness = 26 microns
- Porosity = 40 %

Overcharge Circuit Breaker Safety Feature



Overcharge Circuit Breaker Safety Feature



Battery Design Terminology

- Series -Cells connected - to + to - to +. . .
  - > V=V/cell X Qty of Cells in String: Ex. 3 LiSO2 cells in series=3V x 3 = 9V; 3 Alkaline cells in series=1.5V x 3=4.5V
  - > Current(I) same in all cells in series string
  - > Capacity(Ah) = capacity of one cell in string
  - > Energy(Wh)=Capacity in Ah x V

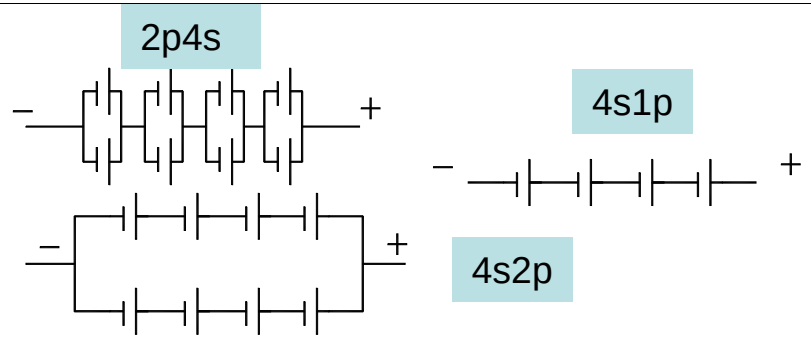
Battery Design Terminology

- Parallel=Cells(or Cell Series Strings) connected with + to + and - to -
  - > V=V/cell(or cell string)
  - > Total Current(I)=Current of each cell(cell string) x qty cells(strings) in parallel
  - > Total Capacity(Ah) = capacity of one cell x qty cells(strings) in parallel
  - > Energy(Wh)= Total Capacity in Ah x V

Battery Design Terminology

- Why Parallel vs Series?
  - > High Current Requirement
    - Divides current by no. parallel legs=multiplies total current capability by no parallel legs
  - > High Capacity Requirement
    - Multiplies Ah capacity by no. parallel legs
- What Are Downsides of Parallel Config.?
  - > Cannot test individual strings when connected internally
  - > Balancing challenge
  - > Special End of Life Phenomena
  - > Voltage drop on diodes

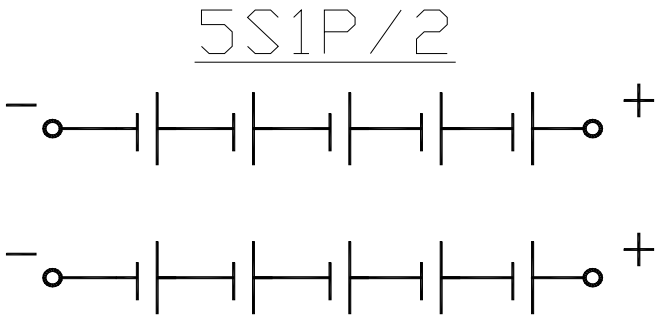
Battery Configuration Nomenclature



Battery Configuration: aSbP-Cell Type

a=qty cells connected in series; b= qty cells in parallel

Battery Design Nomenclature



Battery Configuration: aS1P-Cell Type/n

a=qty cells connected in series; n=qty duplicate strings

Design

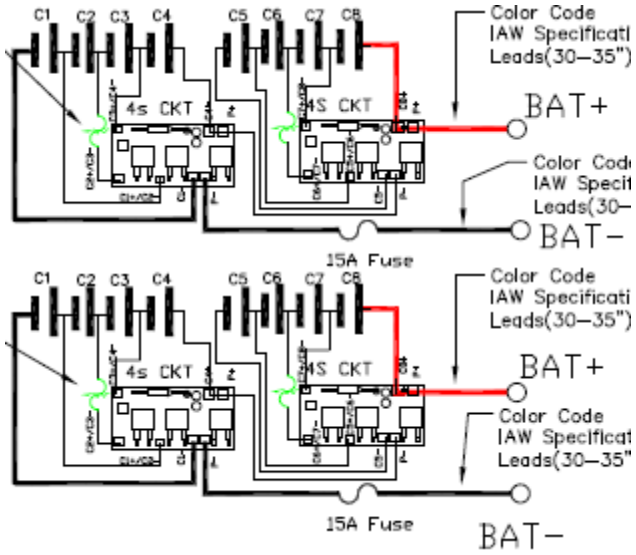
- Standard LiIon Battery Design
  - > Resettable Protection Circuit
    - Overall overcurrent
    - Overall over temperature
    - Over/under voltage at cell level
- Considerations
  - > Application/Use
    - Cyclic usage(charge – use – recharge)
    - Back up power(charged – ready for power as req'd)
  - > Power/environmental
    - High power/high energy
    - Long life/high cycle life
    - Intermittent usage/storage
  - > Temperature operation: charging/discharging

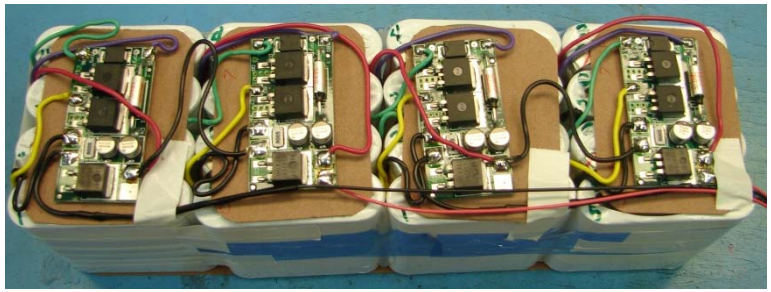
Cost Considerations

- Features
  - > OTS circuits simple design
  - > Bells/whistles
    - Smart circuits
    - Fuel gage
  - > Finish
    - Soft Pack(PVC Shrink)
    - Hard Case
      - Metal (Expensive per piece cost)
      - Plastic (Lower per piece cost; costly tooling)
  - > Connector
  - > Special Agency Qualifications

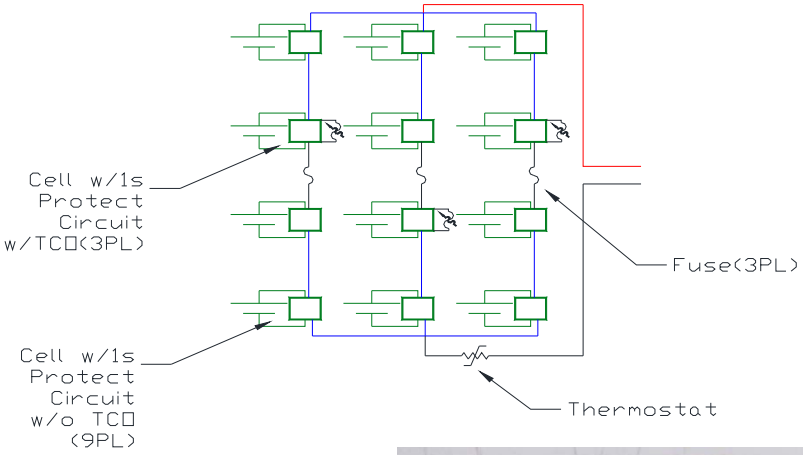
LiIon Battery with 4-cell Protection Modules

8s2p Configuration





LiIon Battery with Individual Cell Circuits



4s3p Configuration