



# Battery Pack Safety

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# Scope

- The issues and battery packs discussed in this presentation will focus primarily on Lithium Ion technology.
- The battery packs associated with this presentation are considered to be LESS than 80Wh in capacity.



# Outline

- Cell Chemistries
- Cell level Safety
- Pack Safety (Protection Circuits)
- Charging
- Approvals



# Chemistries

- The most common battery technologies in Laptop Computers and Portable Data Terminals;
  - NiMH
  - Lithium-ion
  - Lithium Polymer (Just Starting)
- The main issues with all these technologies is their safety in severe over-charge situations. Problem with heat build up and thermal runaway conditions.



# Protection for Lithium-ion Batteries

- There are usually 3 levels of protection against overcharge built into devices using Lithium-ion batteries;
  - Internal devices inside individual cells in a battery pack
  - A “protection” circuit built into the battery pack.
  - A proper charger
- Redundancy is very important to ensure the cells never reach an unsafe voltage.

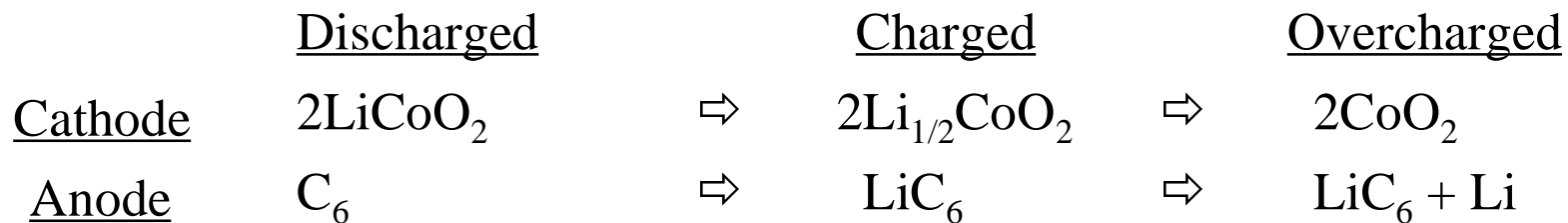
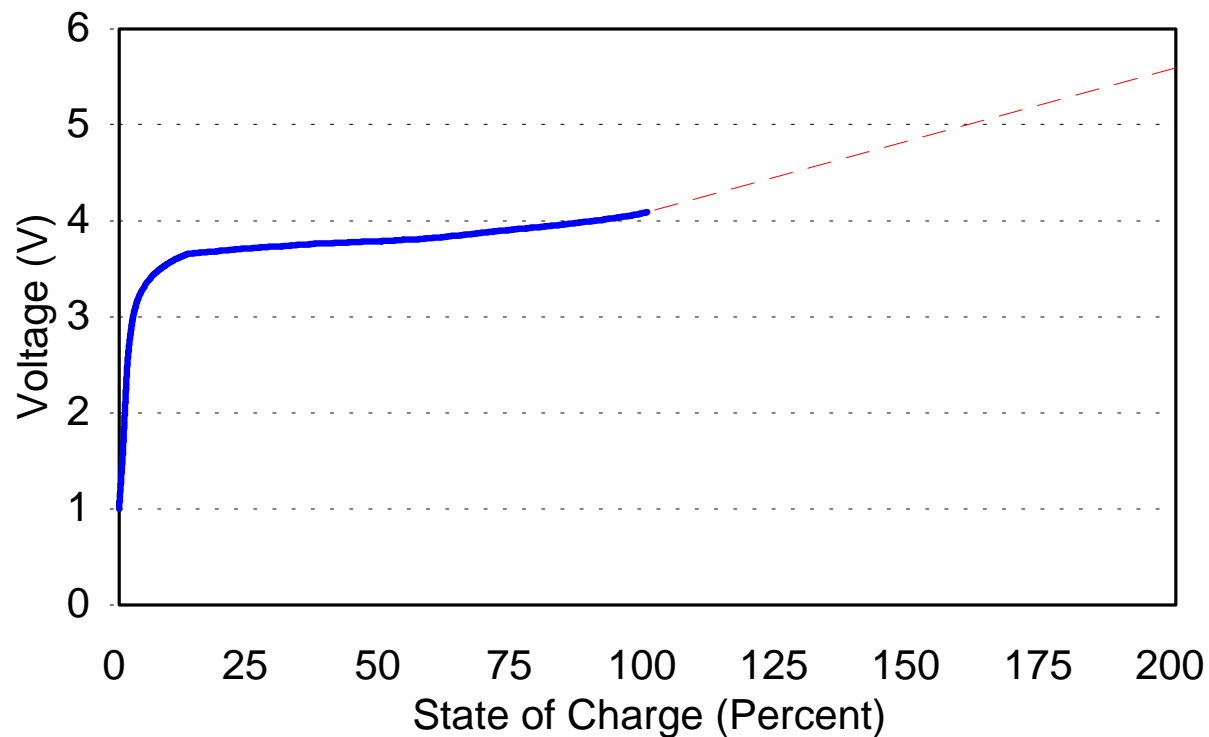


# What Happens on Overcharge

- Cobalt Li-ion cells are designed to operate safely within their normal operating voltage range, but become increasingly unstable if charged to higher voltages.
- Overcharging  $\text{LiCoO}_2$  cells above their designed charge voltage will cause;
  - Lithium metal plating on Anode.
    - Lithium metal is a powerful reducing agent. This is the reason Li-ion was developed.
  - The cathode material becomes unstable, becoming a strong oxidizing agent. (wants to release oxygen).
  - **Heating**
- **The lithium plating and destabilization of the cathode material make the cell more sensitive to thermal runaway. Consider also the cell contains a flammable electrolyte.**

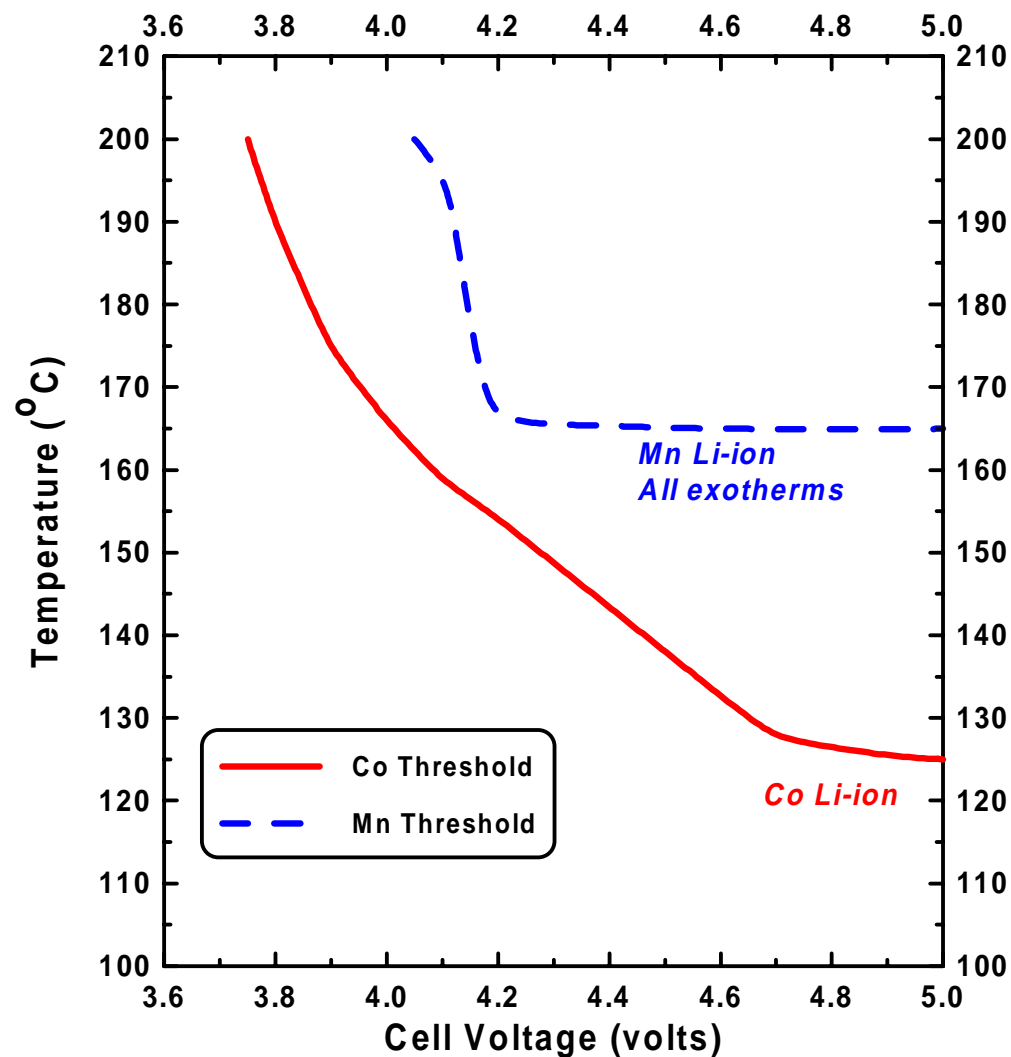


# Charge Characteristics - LiCoO<sub>2</sub>



# Cell Safety - Voltage vs Temperature

- This graph shows a cells tolerance to temperature when charged to progressively higher voltages.
- Points falling above the threshold represent cells that reach thermal run away.



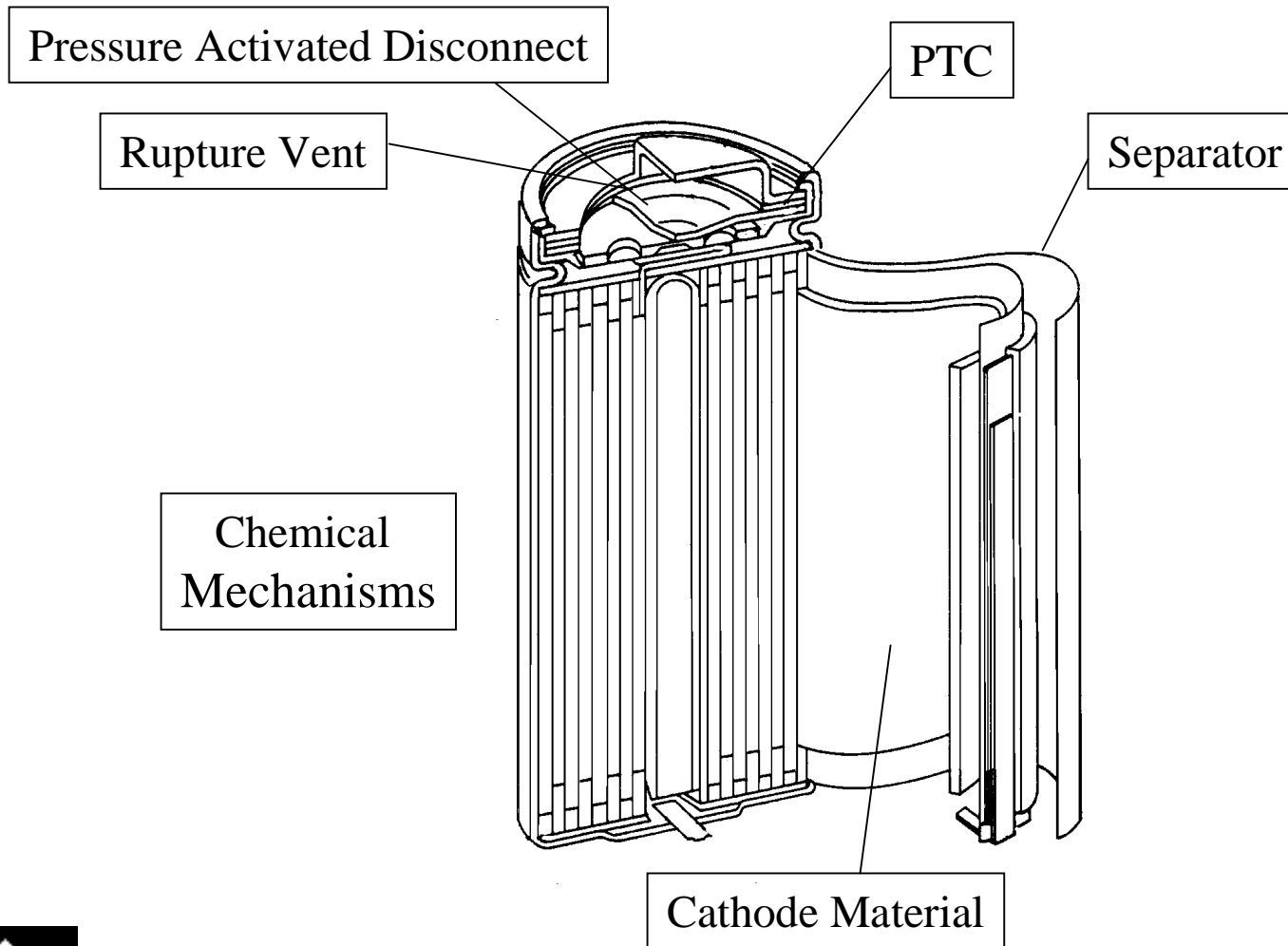
Dr. Jan Reimers et, al. Journal of the Electrochemical Society



# What Happens on Overcharge



# Built in Cell Safety Mechanisms



# Built in Cell Safety Mechanisms

- **Separator**
  - Plastic porous separator material between the anode and cathode electrodes, melts between 120°C and 150°C and the pores close disabling the cell.
- **Disconnect Device**
  - All cylindrical and some prismatic Li-ion cells have a built in electrical disconnect device (switch) for over-charge protection. This device is usually pressure activated on overcharge and permanently opens the electrical connection to the outside. This stops the overcharge before a possible safety incident.



# Built in Cell Safety Mechanisms

- **PTC (Polyswitch™)**
  - Usually built into the header of a cylindrical cell.
  - Used to limit currents in an over-charge condition (tripped by heat).
  - Also used to limit short circuit currents from a single cell to a safe level.
- **Rupture Vent**
  - In case of large internal pressure buildup (under thermal or mechanical abuse situations) safely releases the gas pressure, the cell doesn't explode.
- **Chemical**
  - Biphenol (NEC Moli Energy)
    - A voltage triggered polymer which causes the cell to go high resistance after overcharge. Increases cells safety to mechanical or thermal abuse after overcharge.

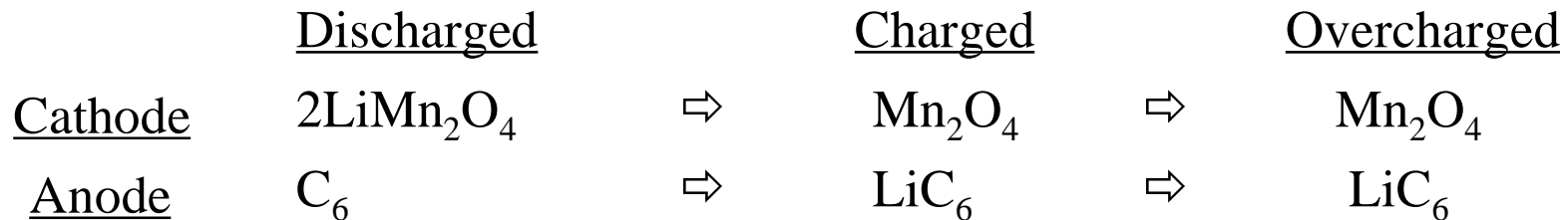
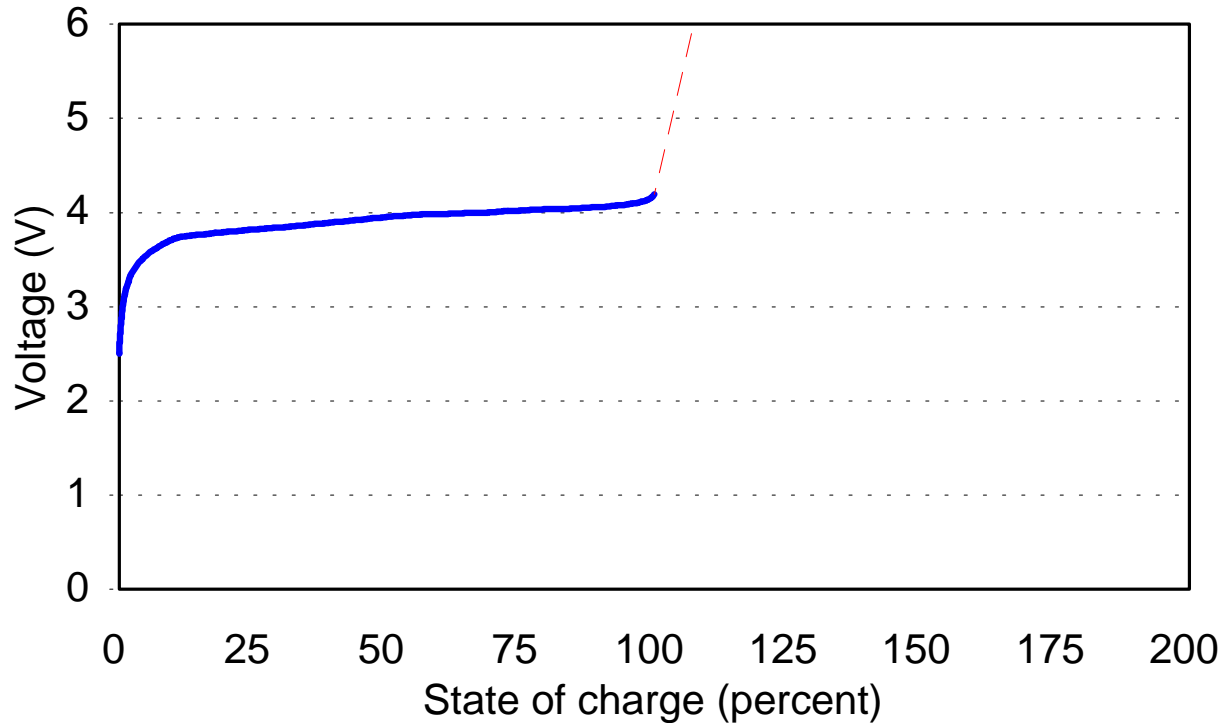


# Built in Cell Safety Mechanisms

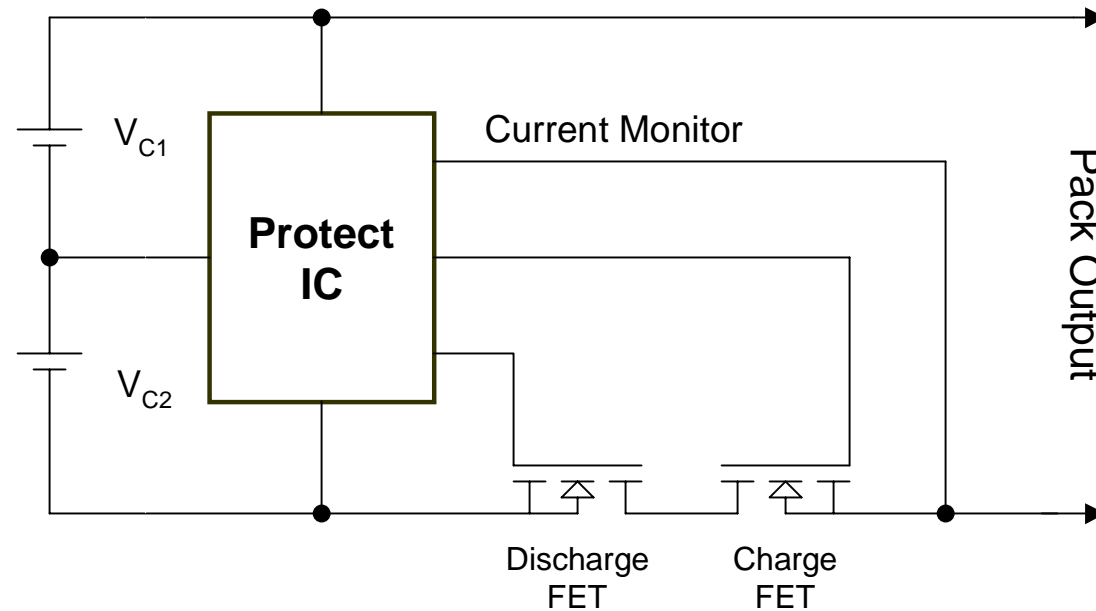
- **Cathode Material -  $\text{LiMn}_2\text{O}_4$** 
  - An overcharged Manganese cell is not much different than a normally charged cell.
  - For  $\text{LiMn}_2\text{O}_4$ , essentially all Lithium is removed from the cathode during normal charge (little excess lithium).
  - Overcharging  $\text{LiMn}_2\text{O}_4$  cells above their designed charge voltage will cause;
    - Minimal lithium plating on the Anode.
    - The cathode material remains stable.  $\text{Mn}_2\text{O}_4$  will not liberate oxygen until above 500 degrees C.
    - **Heat**
  - The cell still has a flammable electrolyte, but has more stable anode and cathode materials.



# What Happens on Overcharge - $\text{LiMn}_2\text{O}_4$



# Pack Protection Circuitry

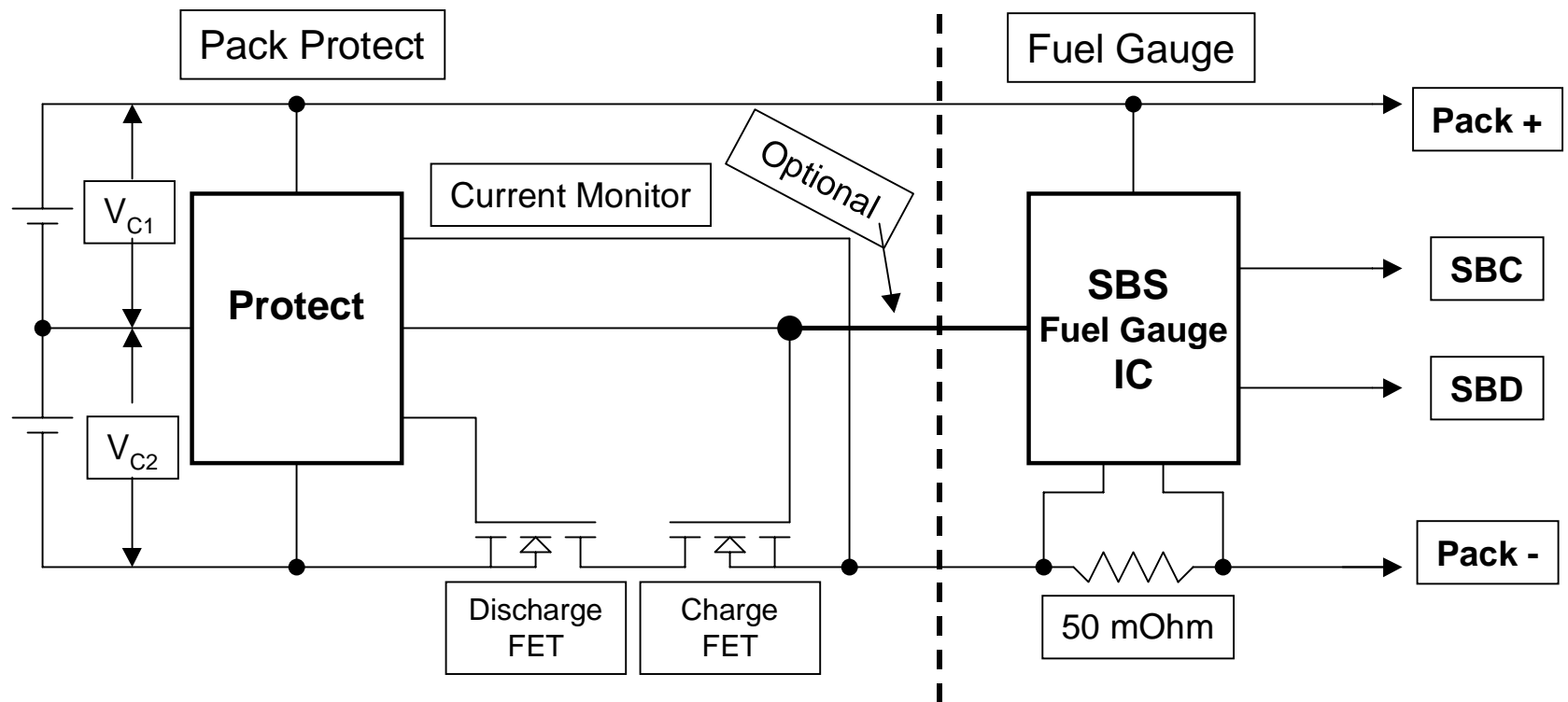


- Each Cell's voltage is monitored Individually ( $V_{C1}$ ,  $V_{C2}$ )
- Current is monitored through FET's
- One FET Disconnects on **Over Charge**
- Another FET Disconnects on **Over Discharge**



# Protection / Fuel Gauge Circuitry

- Redundancy
  - Always use an independent pack protect IC
  - SBS Gauge may monitor FET status and send an error message to the host and charger to prevent overcharge.



# Additional Pack Protect Devices

- **PTC**
  - Used as an additional device for short circuit protection. This device limits the current to and from the cells if the pack protect fails.
- **Thermal Fuse**
  - Placed in between cells to monitor temperature. If the cell temperature becomes too high, fuse will disconnect permanently. This device will disable charging in a case where the pack protect circuit fails on charge.

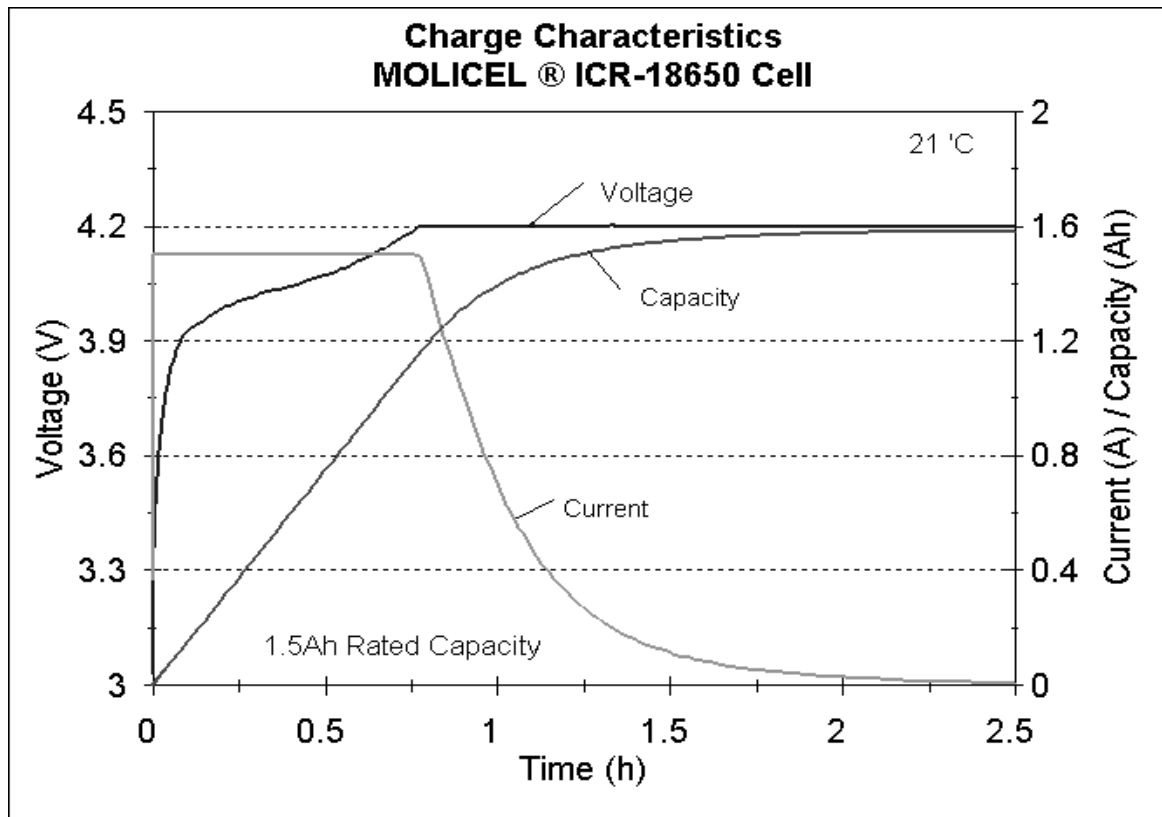


# Charging Lithium-ion Batteries

- Constant Current, Constant Voltage (CCCV)
  - Most common method of charging Lithium-ion cells.
  - Charge is terminated at some minimum current.
  - Current is limited to 1C.
  - Approximate charging time 2.5 hours.
- Pulse Charging
  - Charge control is inside battery pack.
  - Battery pack is supplied with a constant current source.
  - Charge times can be reduced.
  - Pulse charging can reduce cycle life of Lithium-ion batteries.



# Charge - Constant Current, Constant Voltage



- Most common charge method for Lithium-ion batteries.
- Charge is terminated when the current tapers below a preset value (50-100mA/cell).
- Battery charges to 70-80% of capacity in one hour. Full charge takes about 2.5 hours.



# Charging Safety Issues

- **Charging over 1C.**
  - High charge currents can cause Lithium plating.
- **Terminate charge, limit voltage.**
  - Lithium-ion cells do not have a chemical shuttle mechanism like Nickel based chemistries. Charging over the specified charge voltage will decrease the safety of the cell in secondary abuse situations.
- **Avoid charging at low temperatures.**
  - Can cause lithium plating. Some manufacturers allow charging at low temperatures by reducing charging currents.



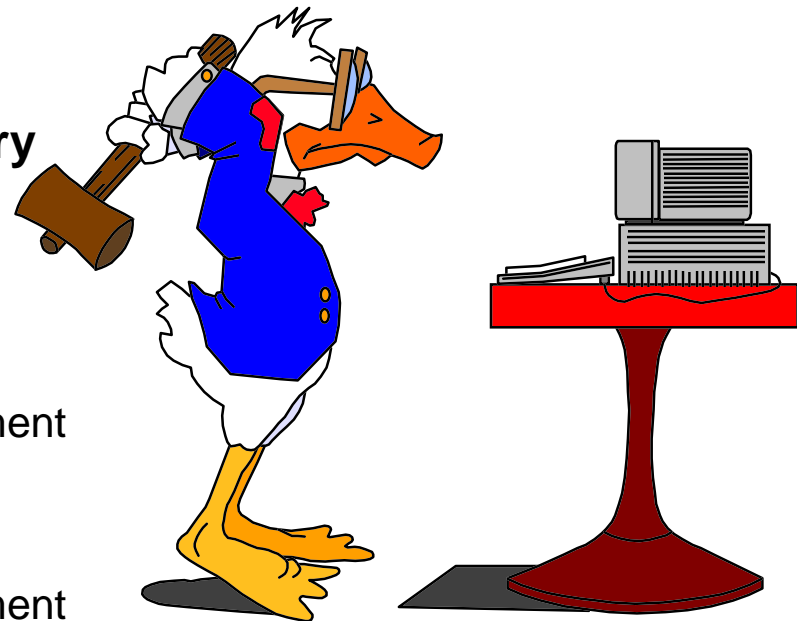
# Discharging Safety Issues

- **Discharging below 0 volts can cause;**
  - Formation of copper shunt. If cell is driven negative long enough, a 0 ohm shunt will form and permanently disable the cell.
  - If shunt is only partially formed, charging at 1C rate will cause excessive heat. Therefore it is important to charge cells at C/10 rates if the cell voltage is low.
- **In a normal Li-ion battery pack the protection circuitry prevents the cells from being driven into reversal on discharge.**



# Approvals

- **Cells**
  - UL1642
  - IEC
- **Battery Packs**
  - **USA - Underwriters Laboratory**
    - Individual Lithium-ion cells - UL1642, Safety Standards for Lithium Batteries.
    - Pack UL1950 - Safety of Information Technology Equipment
  - **Canada - CSA**
    - CSA C22.2 NO 950 - Safety of Information Technology Equipment
  - **Europe - TUV**
    - EN 60950 - Safety of Information Technology Equipment



# SBS Battery Pack Safety Guideline

- **A SBS battery pack safety guideline is currently under development.**
- **Input from other SBS member companies is welcome and appreciated.**

