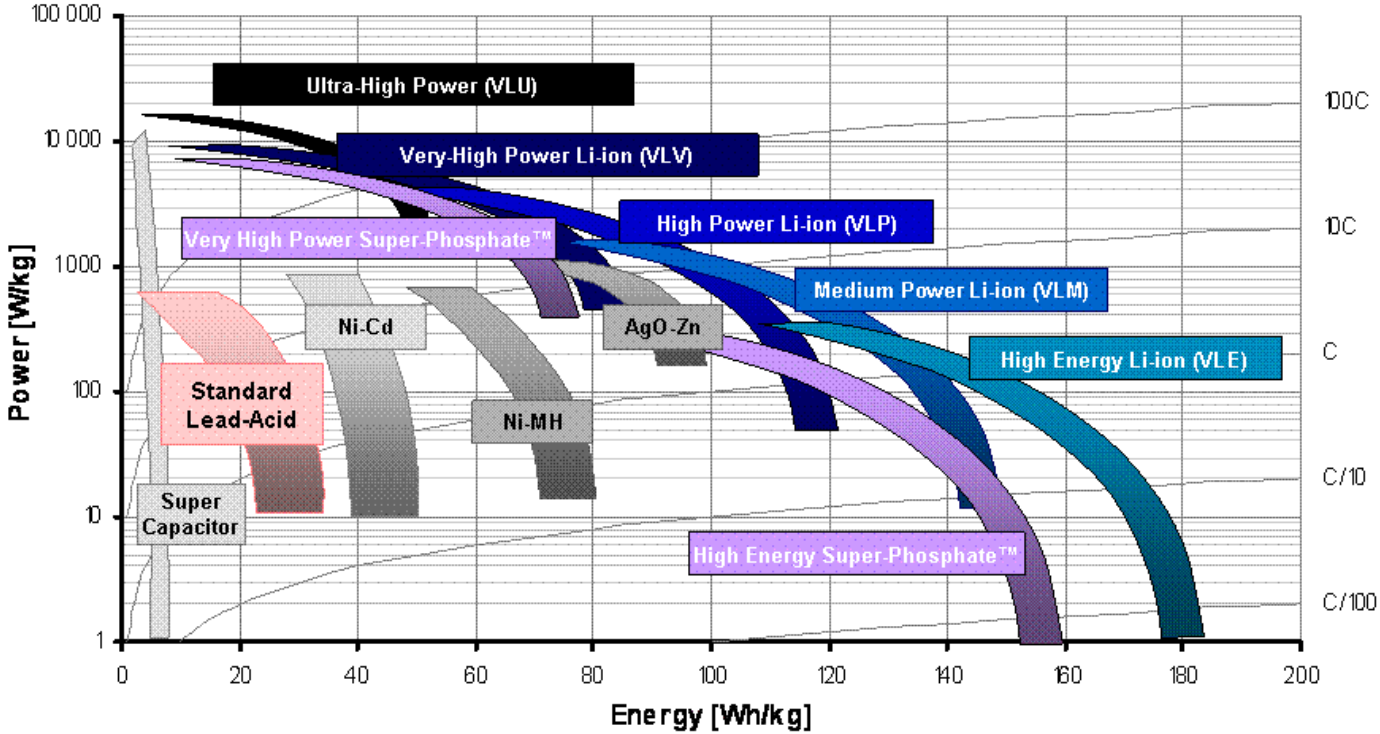
The Li-ion advantage



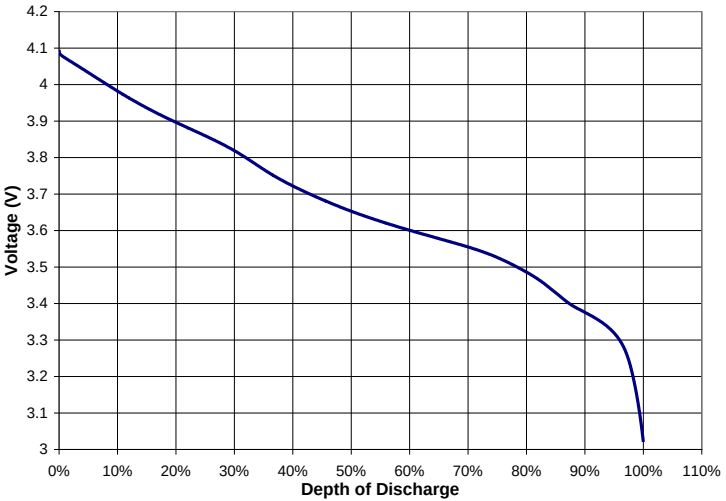
Cylindrical lithium-ion cells

Cell	Classification	Capacity	Weight (kg)	Volume	Discharge Power (kW/kg)			Specific Energy (Wh/kg)	Maximum Discharge (continuous at 25ºC)
					200 ms	2s	Continuous		
VL5U	Ultra High Power	5 Ah	.35	.16 L	30	20	16	58	2000
VL3A	Very High Power	3 Ah	.21	.091 L	15	9	6	70	350
VL6A	Very High Power	6 Ah	.34	.16 L	12	7	6	68	750
VL12V	Very High Power	14 Ah	.64	.27 L	12	7	6	74	1500
VL10VFe	Very High Power (Super-Phosphate™)	12 Ah	.60	.27 L	7	5.5	5	66	1750
VL22V	Very High Power	23 Ah	.98	.41 L	14	9	6	84	2500
VL34P	High Power	33 Ah	.94	.41 L	9	7	2	120	500
VL30PFe	High Power (Super-Phosphate™)	30 Ah	.94	.41 L	2	2	1.7	100	500
VL52E	High Energy	52 Ah	1.0	.48 L			.19	190	52
VL45EFe	High Energy (Super-Phosphate™)	44 Ah	.90	.48 L			.17	160	50

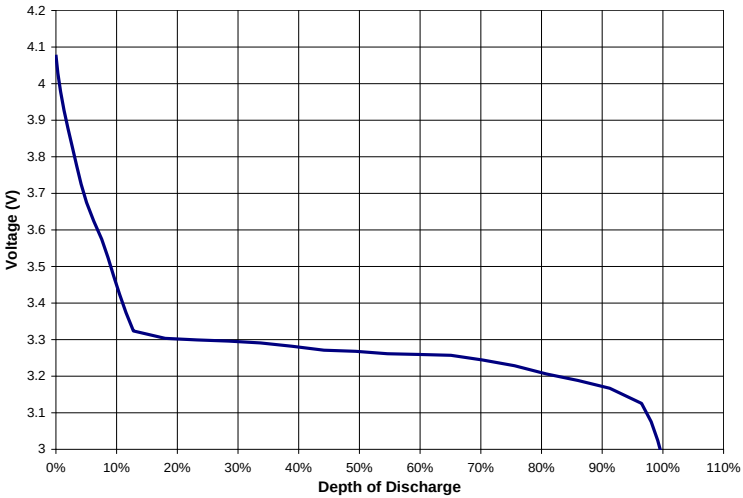
Dimensions

Diameter (mm)	Electrode	Can Length (mm)									
		60		99		152		173		208	
		NCA	LFP	NCA	LFP	NCA	LFP	NCA	LFP	NCA	LFP
34	Energy										
	Power										
	VHP	**VL1A**		**VL3A**		**VL6A**					
	UHP					**VL5U**					
47	Energy										
	Power					**VL25P**					
	VHP					**VL12V/VL15V**	**VL10VFe**				
	UHP										
54	Energy									**VL52E**	**VL45EFe**
	Power							**VL34P**	**VL30PFe**		
	VHP							**VL22V**	**VL18VFe**		
	UHP										

Technology Comparison



Lithium Ion NCA Discharge Curve

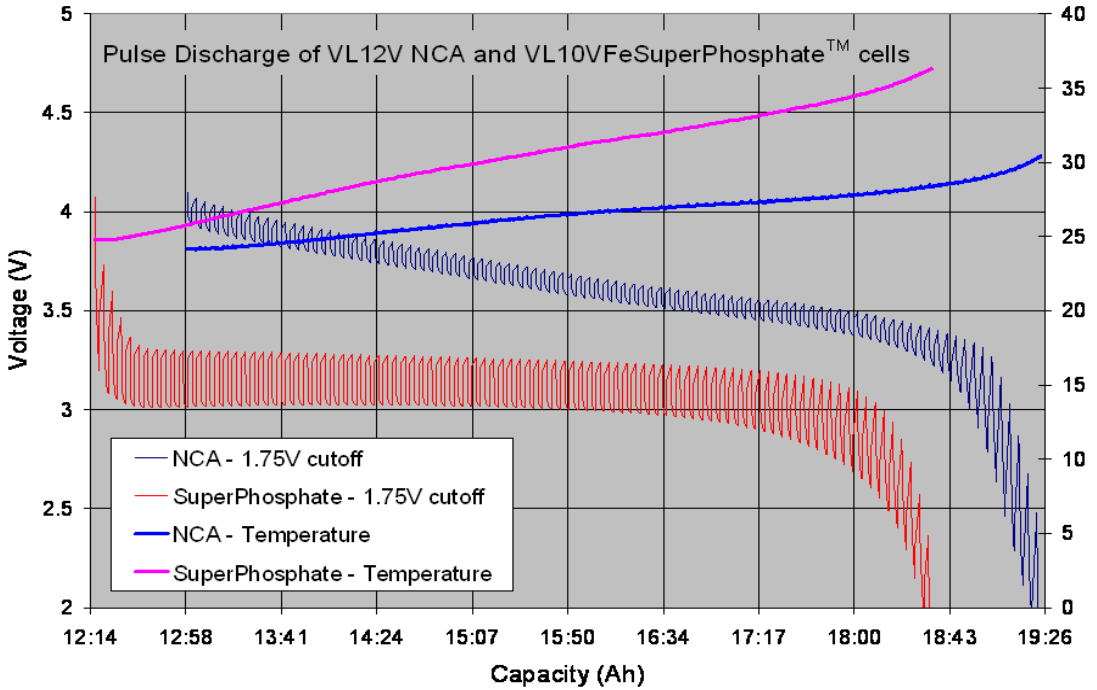


Super-Phosphate™ Discharge Curve

- The reduced energy density and specific energy of Super-Phosphate™ is due to:
  - the difference in discharge curves and
  - the packing density of the active material on the positive electrode.

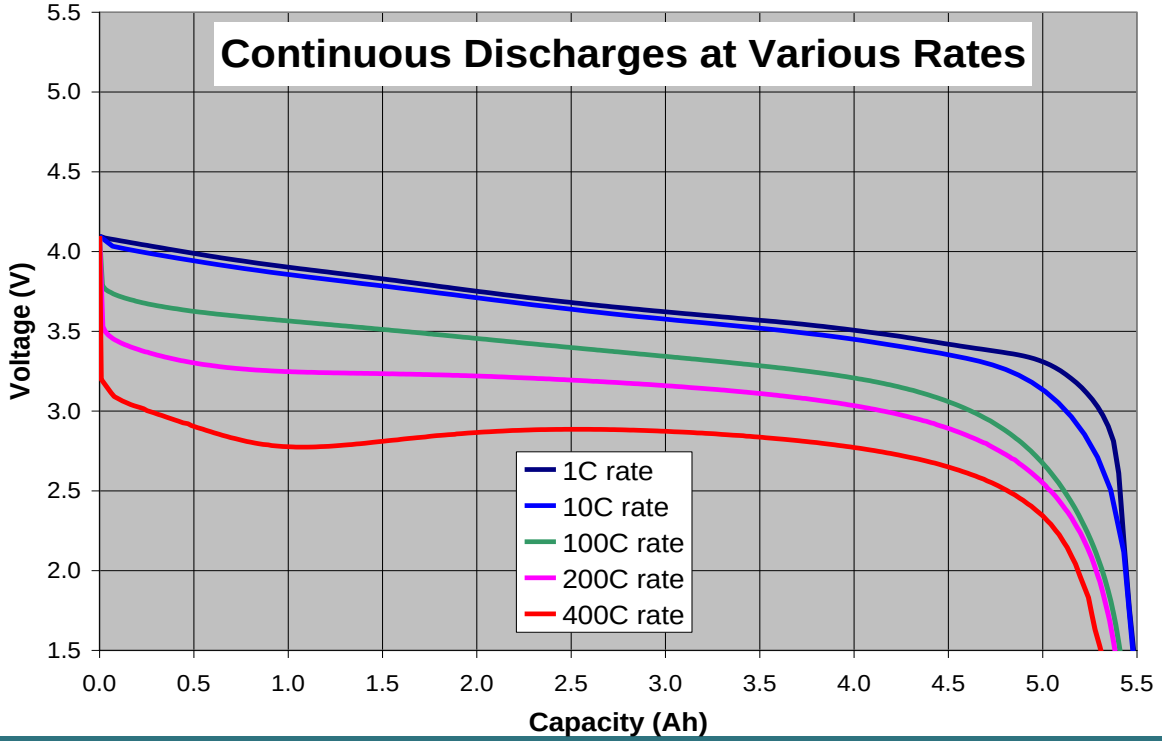
Comparison Between NCA and Super Phosphate® VLV Chemistries

- 50% duty cycle discharge at 250A and 2 second pulsing

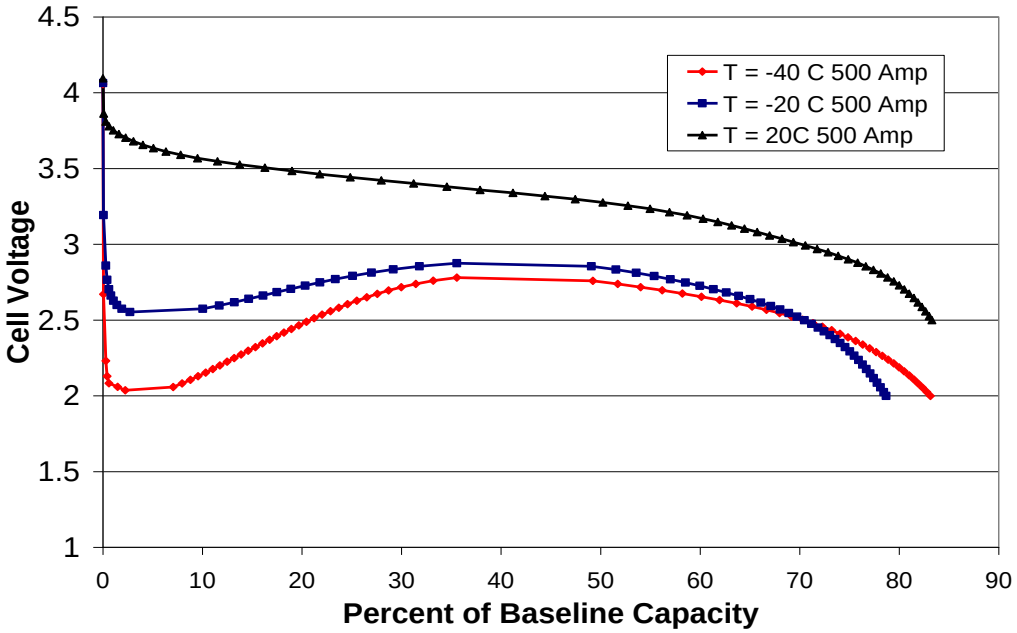


U Technology

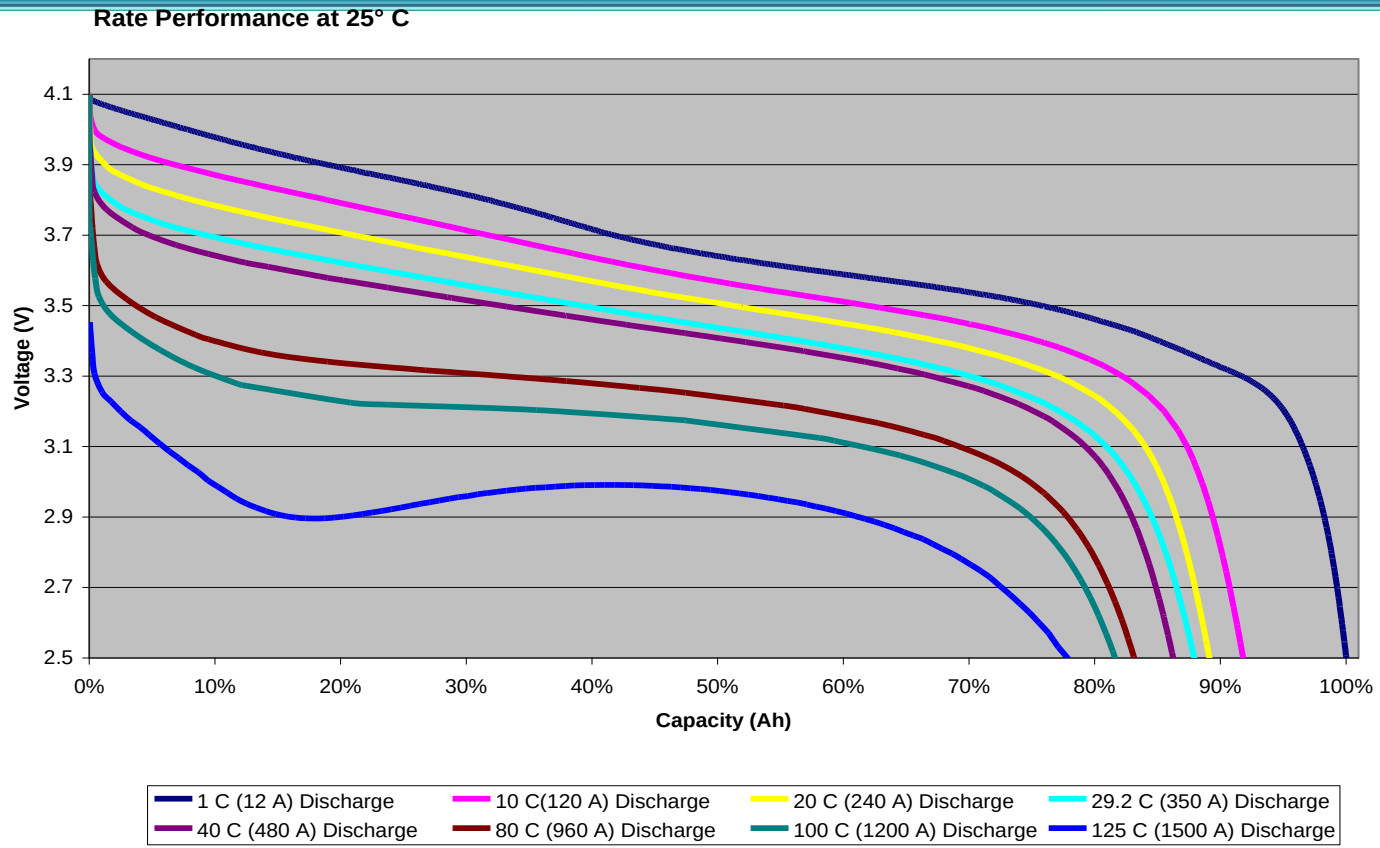
Testing at 25°C



- Constant 500A (100C) current discharge at 20°C, -20°C and -40°C

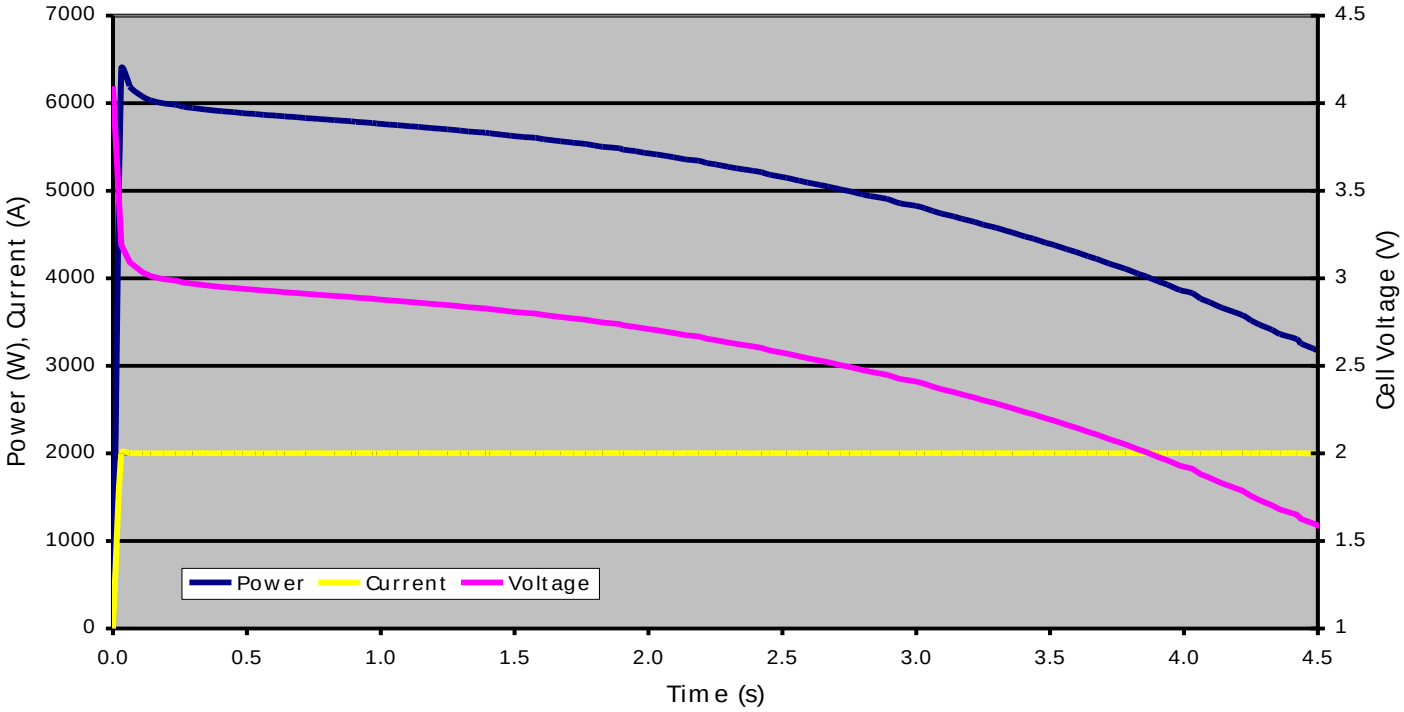


V Technology

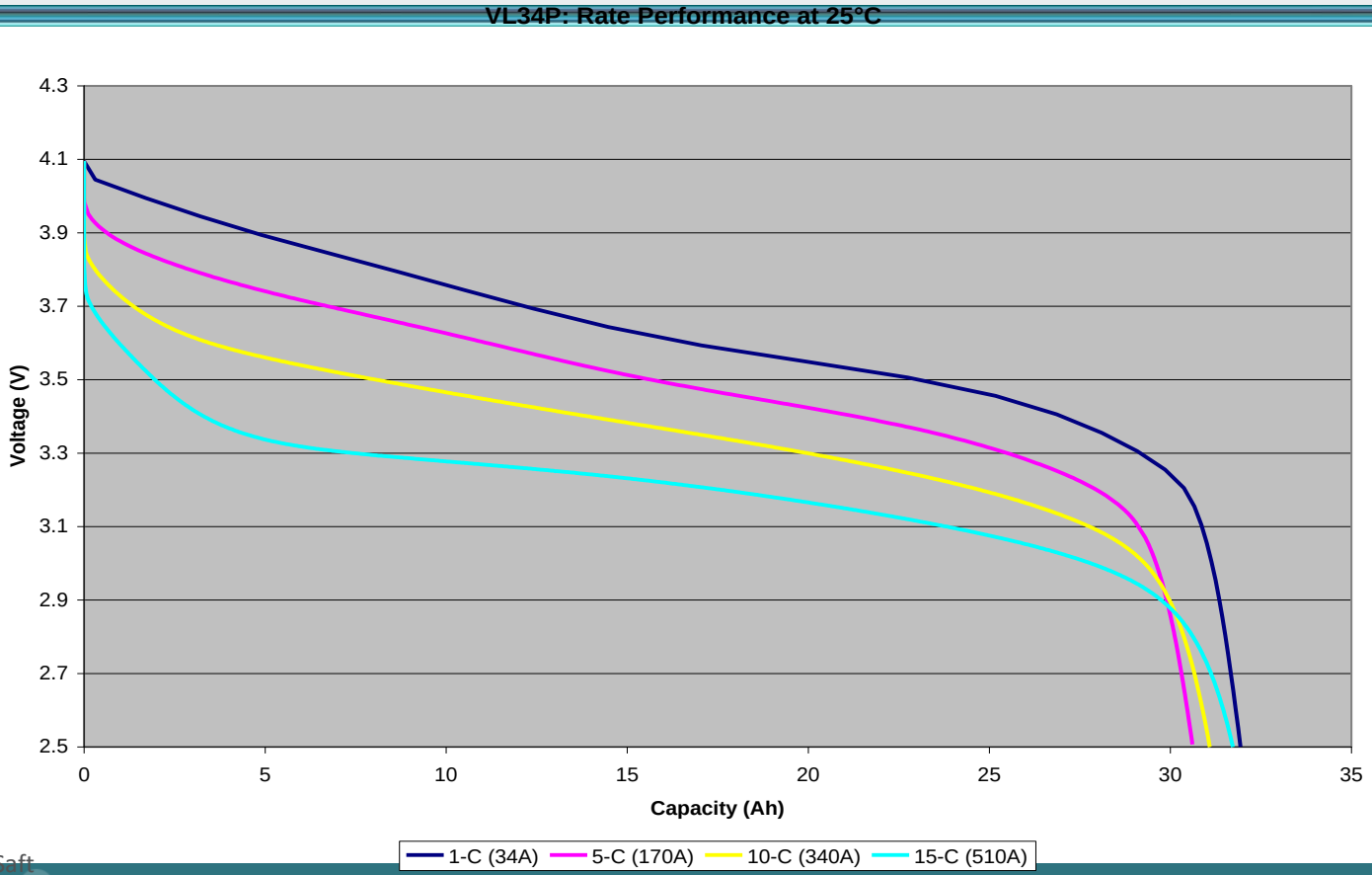


V Technology

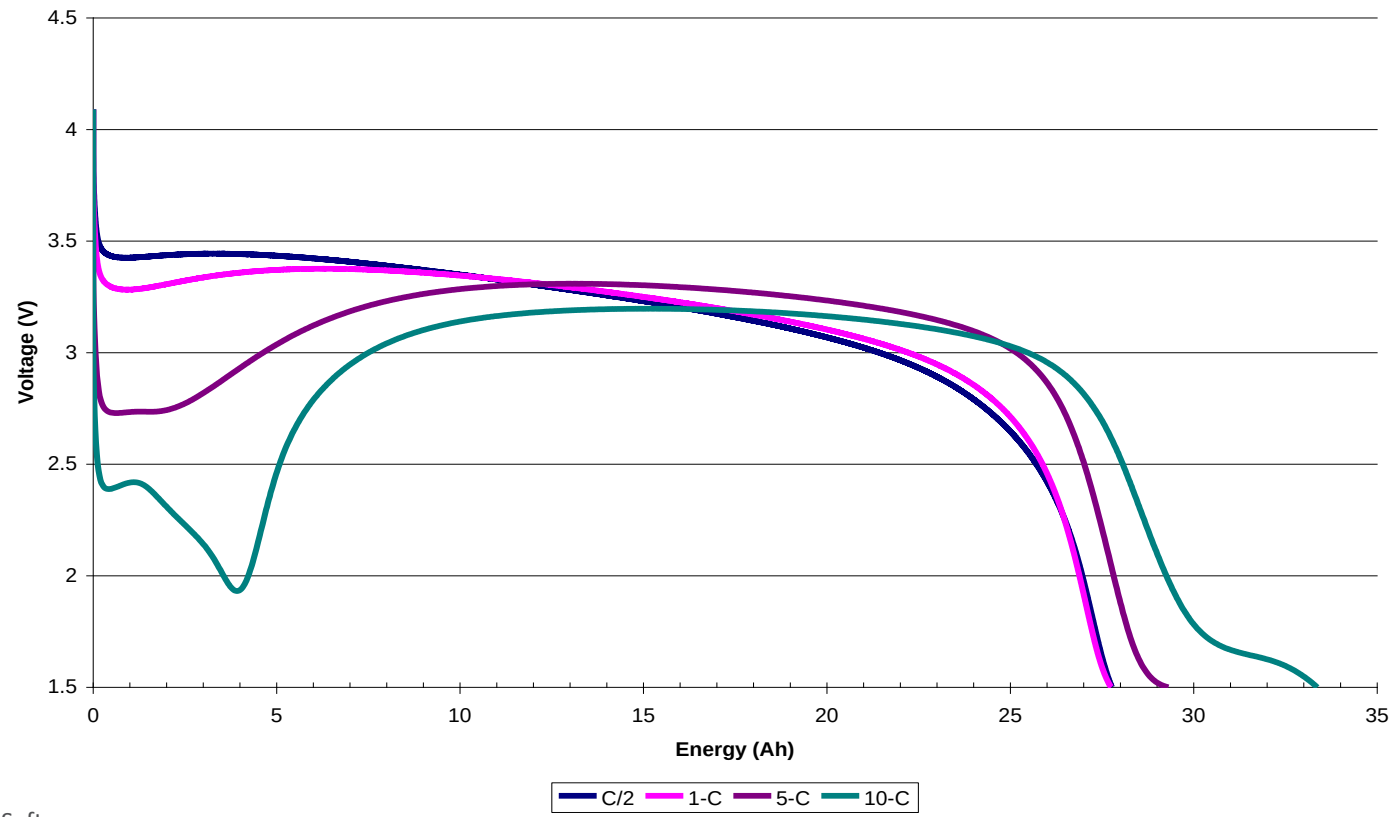
Energy Delivery at 2000Amps/25C, 4.1V/2.5V



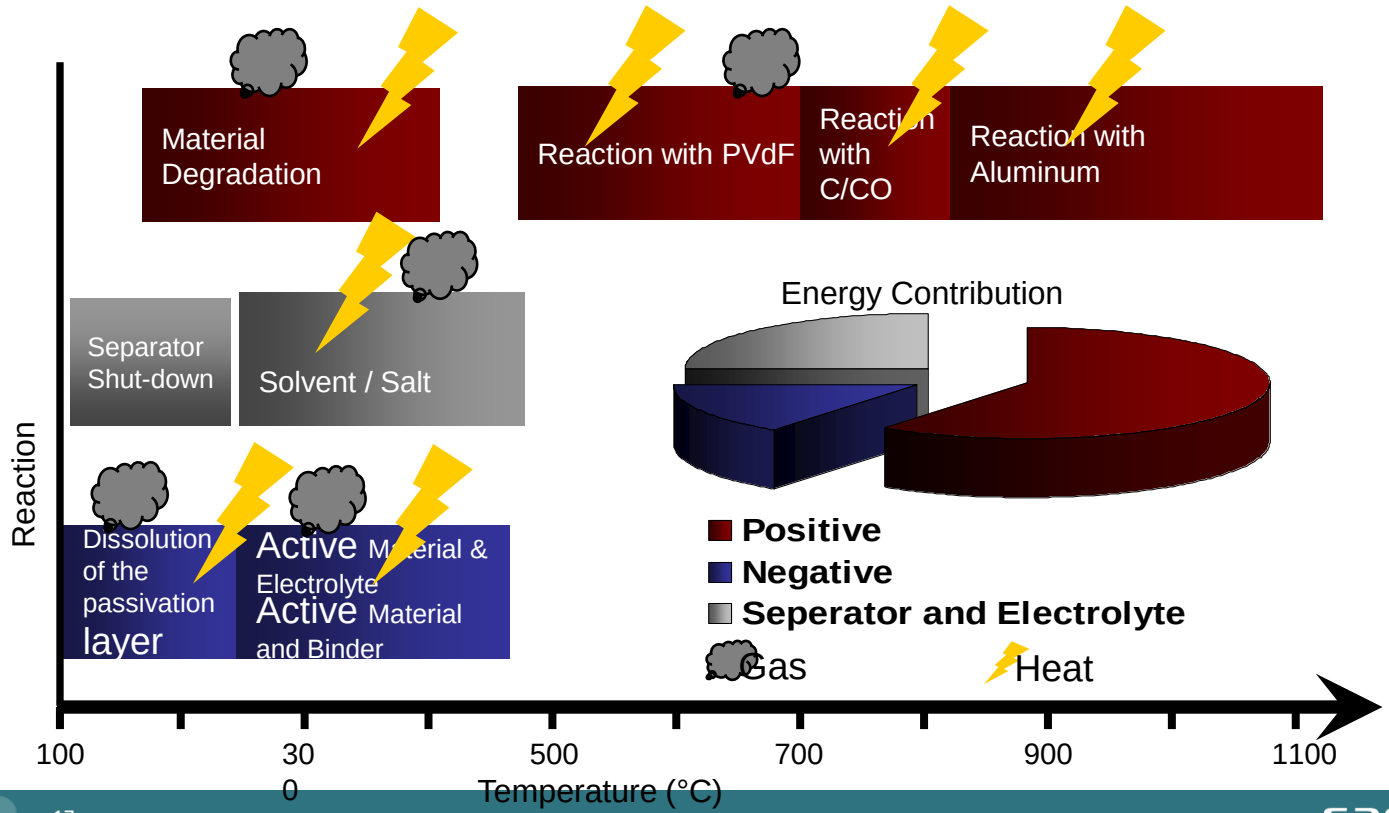
P Technology



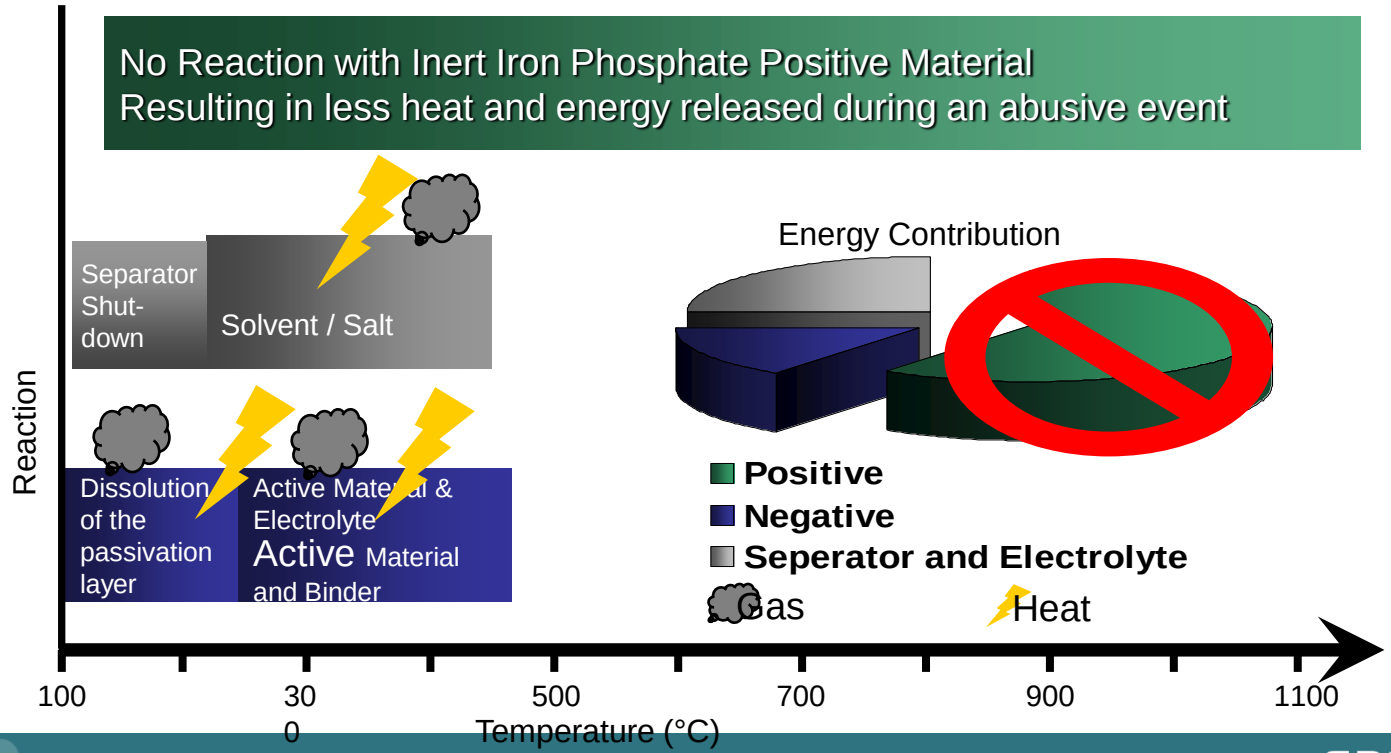
P Technology



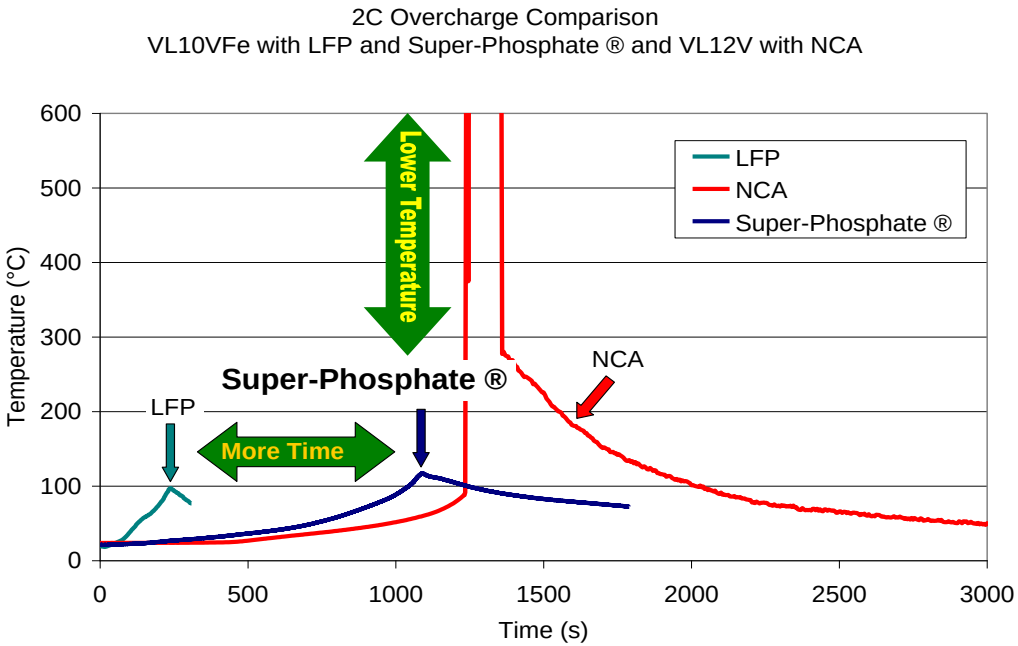
Reactions in an Abusive Event
Metal Oxide



Reactions in an Abusive Event
Iron Phosphate



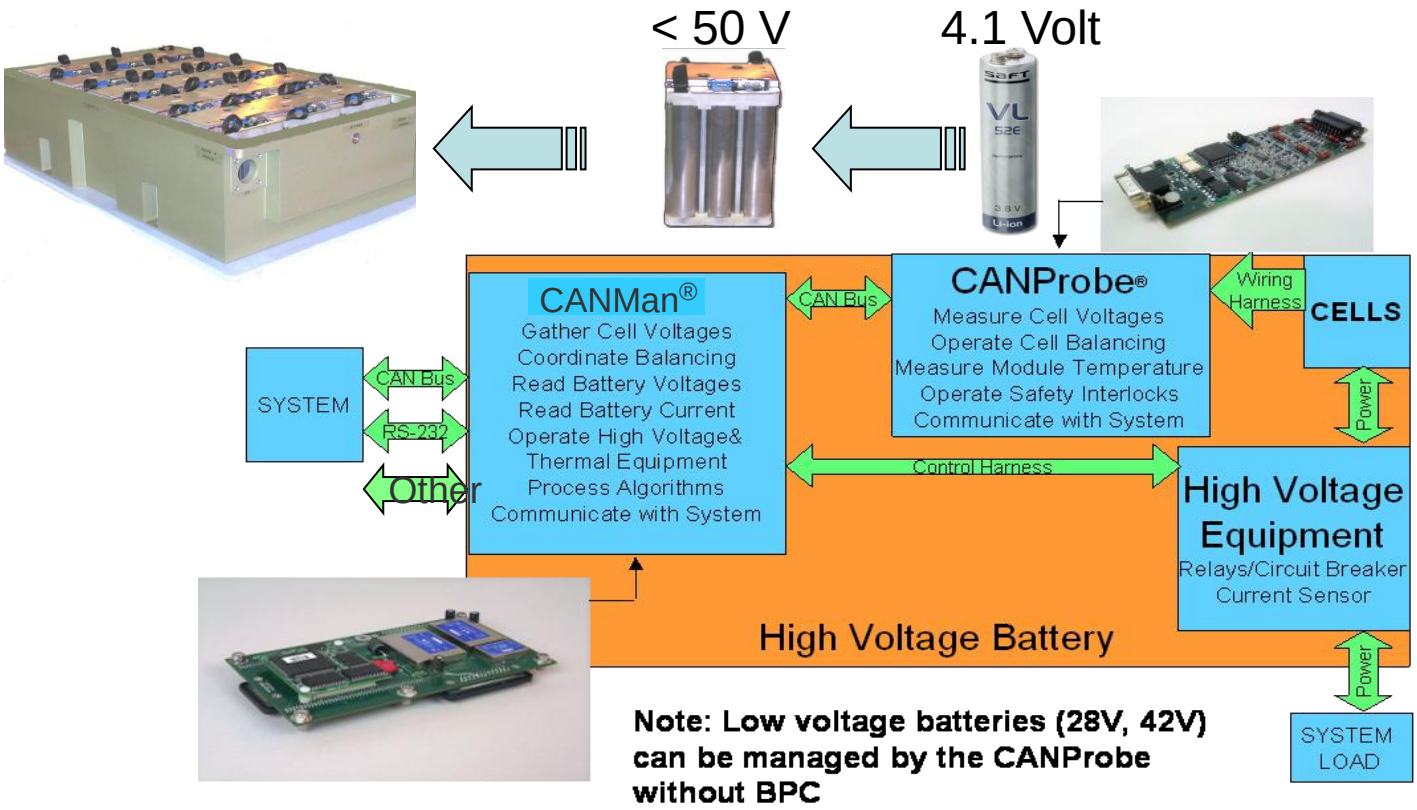
Overcharge Comparison
Super-Phosphate™ versus NCA and Iron Phosphate



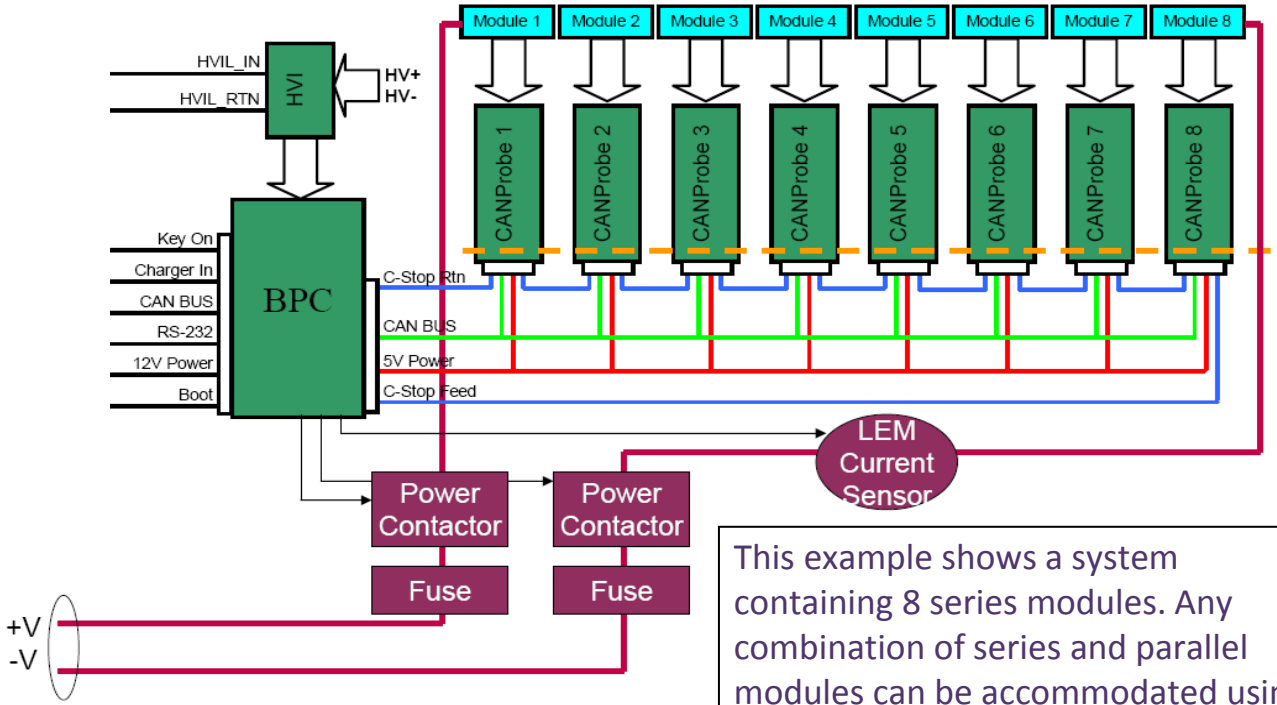
- Super-Phosphate™ is more tolerant to overcharge compared to:
  - > Standard $LiFePO_4$ reaches the event very fast
  - > NCA releases more energy

Battery Systems

Safety and Reliability through System Design

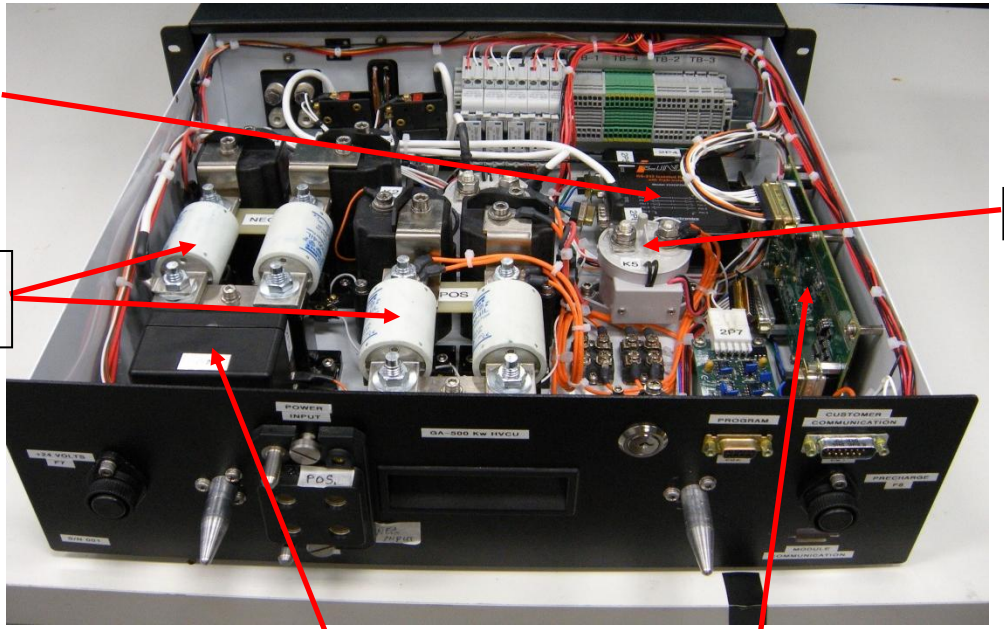


Typical Battery System Architecture



This example shows a system containing 8 series modules. Any combination of series and parallel modules can be accommodated using this architecture.

Example Cabinet
HVCU



Summary of System Features

- Module Level
  - Cell Voltage monitoring
  - Cell Balancing
  - Temperature measurement
  - CAN communications to system controller
- System Level
  - Gather CAN data from Modules
  - Coordinate inter-module balancing
  - Measure battery voltage
  - Measure battery current
  - Short Circuit Protection
  - Monitor Safety Circuits (including Charge Stop (C-Stop), Emergency Stc Detection)
  - Redundant control of overcharge safety interlocks
  - Provide communications with host system / Battery Interface GUI
- Battery Interface GUI
  - State of Charge Measurement
  - Battery Voltage Calculation
  - Interface with charger / Oversight of Charge Algorithm