

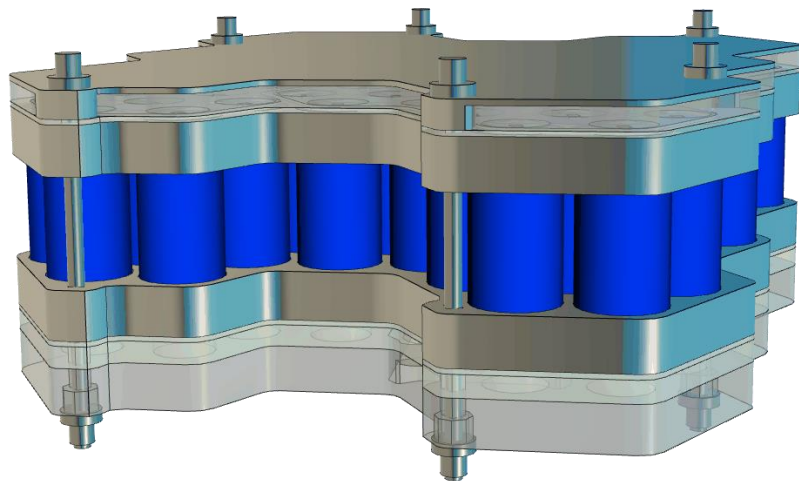
**BETA**  
SIMULATION SOLUTIONS

**ANSA & META**  
for Battery  
Electromagnetic Simulations

**Compression Load**

**Electromagnetic  
Components**

**Thermal**



**Coupled simulation in  
time domain**

Why do we need Electromagnetic Simulations?

What are the challenges arising?

How can this topic be expanded?

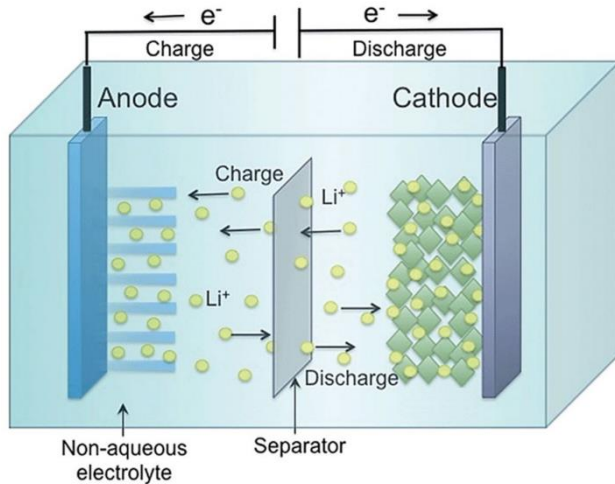
Rapidly increasing demand in electromagnetics

Battery Simulations in Electric Vehicles

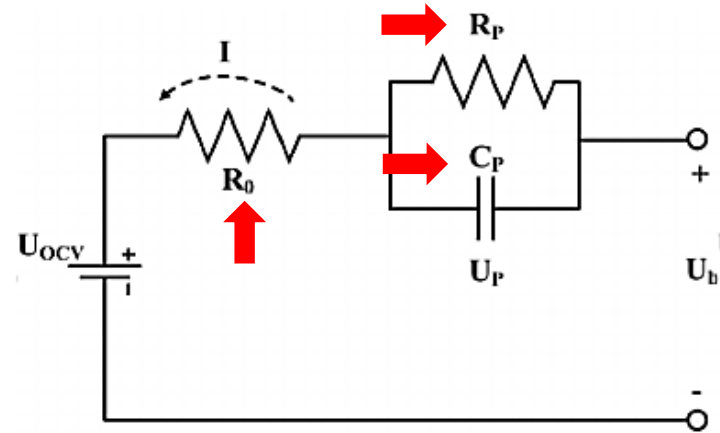
Tight Control of: Temperature, Voltage, Stresses

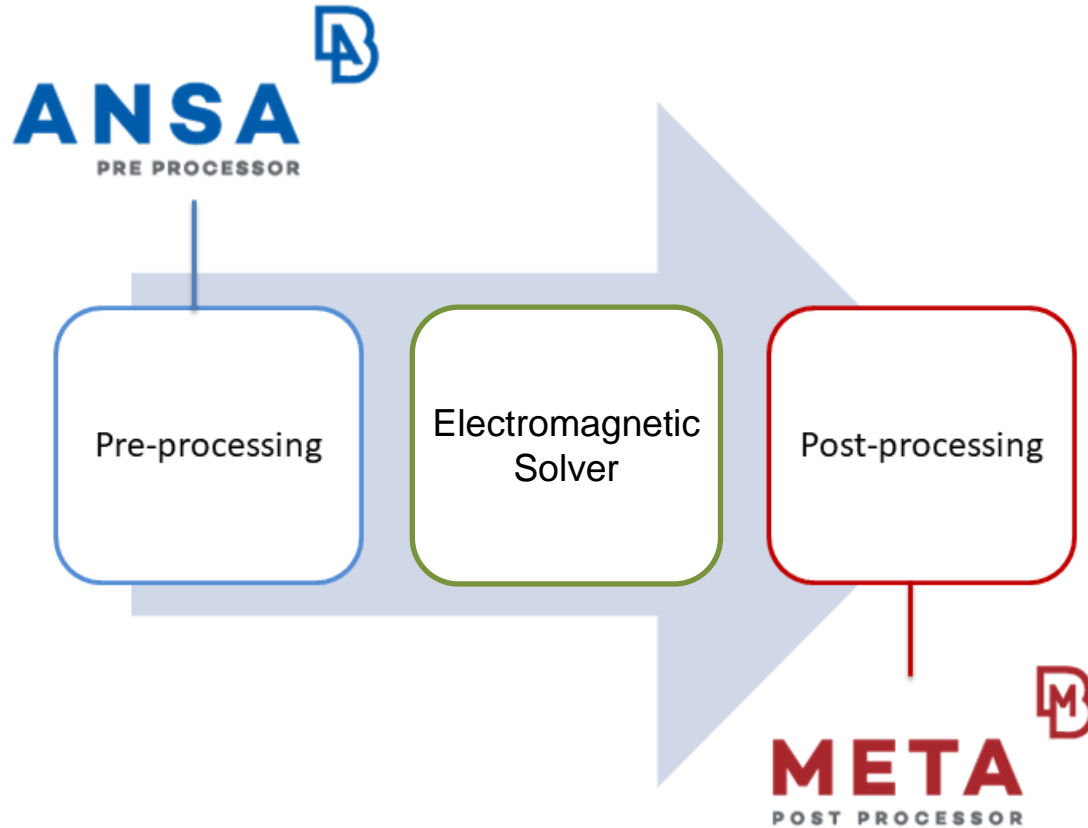
Lithium-Ion Battery Technology

## Battery Circuit



## Randles Circuit

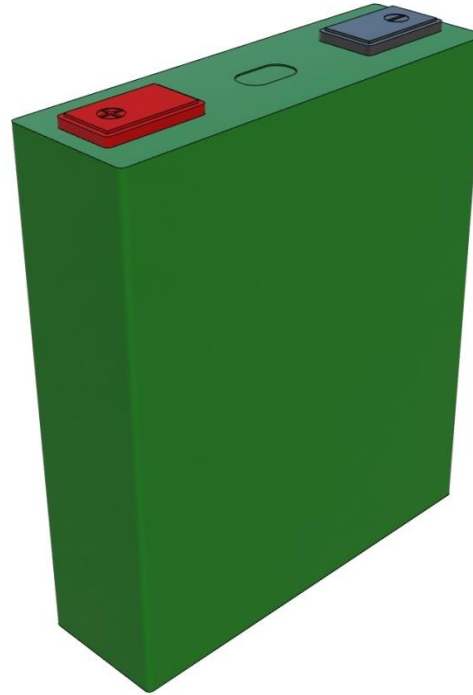




21700 Cylindrical battery



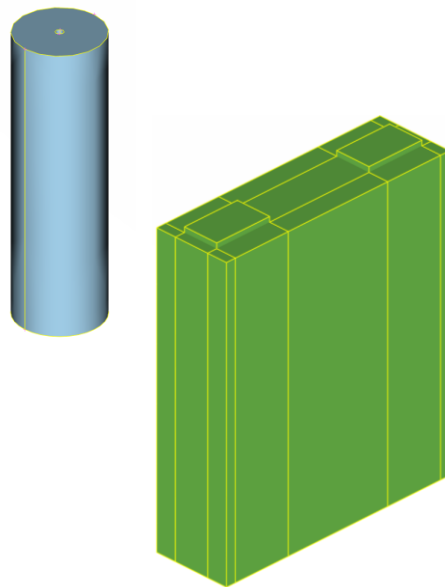
Square battery



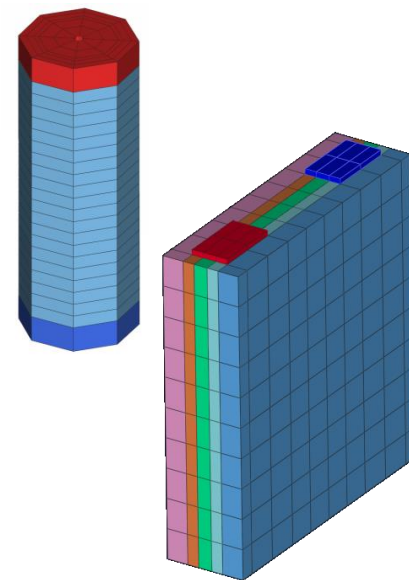
Import CAD file



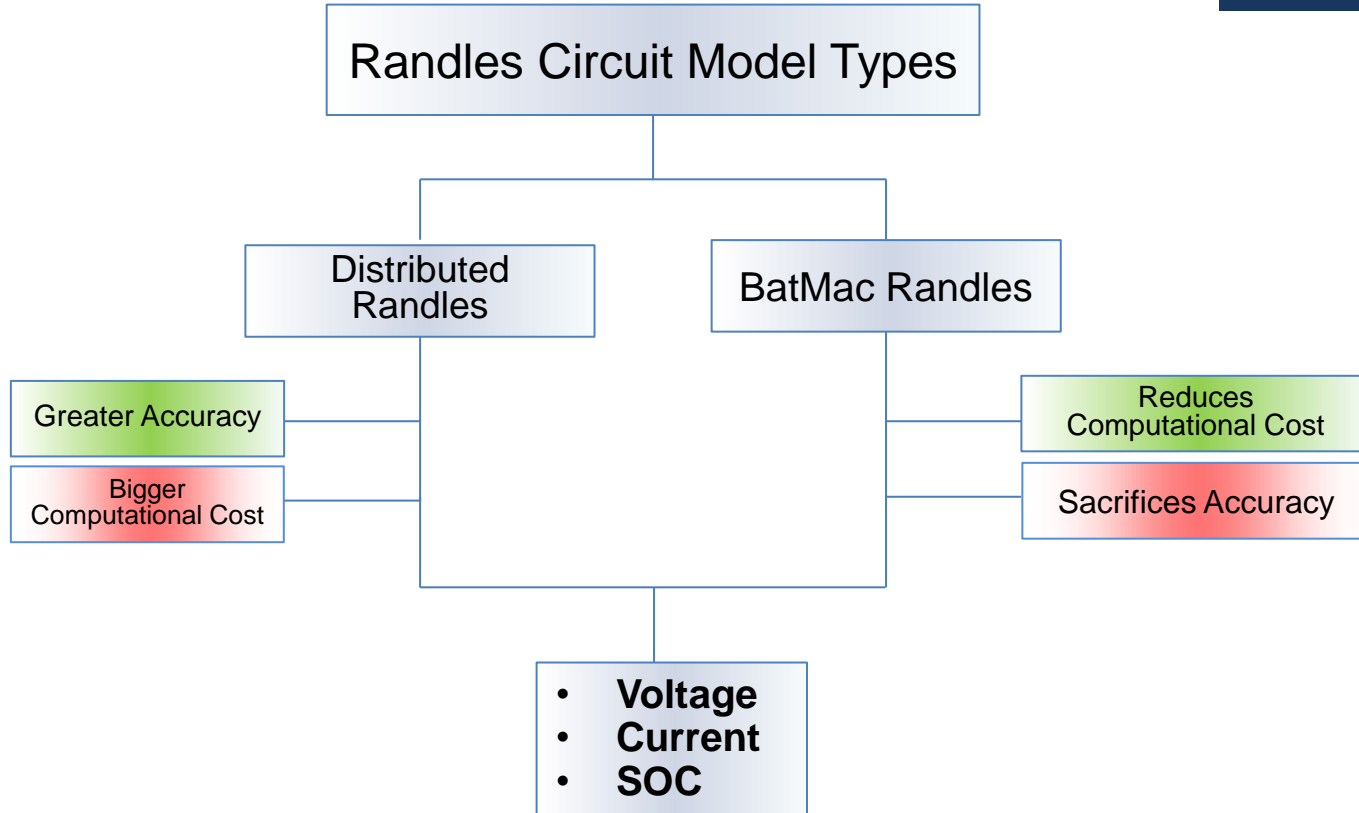
Defeaturing

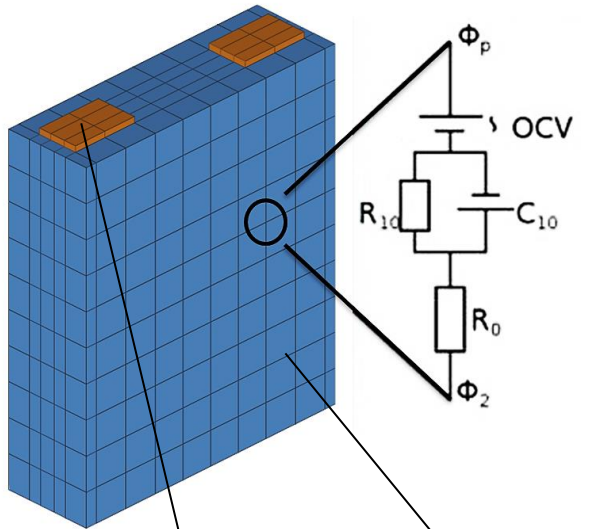


Finite Volume Mesh









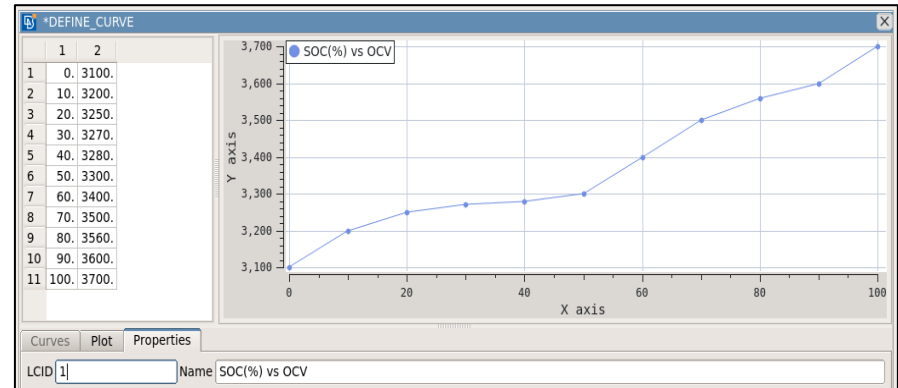
EM\_MAT\_006

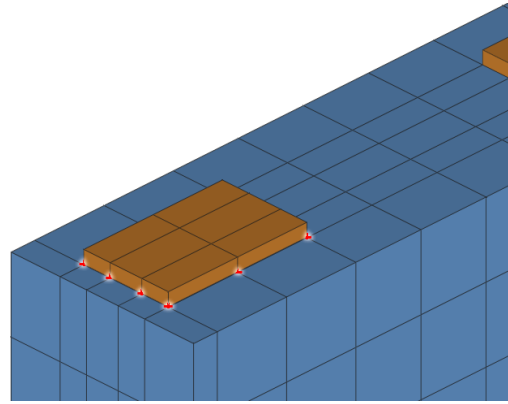
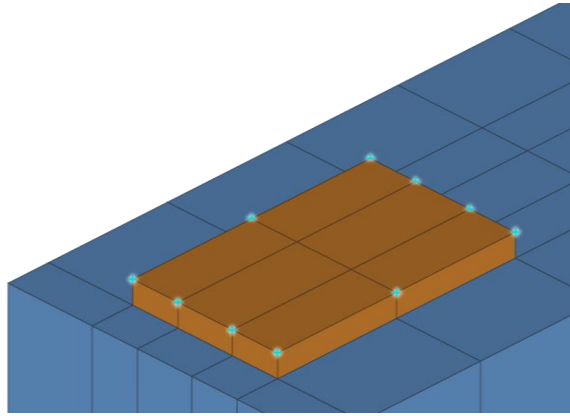
EM\_MAT\_001

Two-material setup

Electromagnetic properties definition

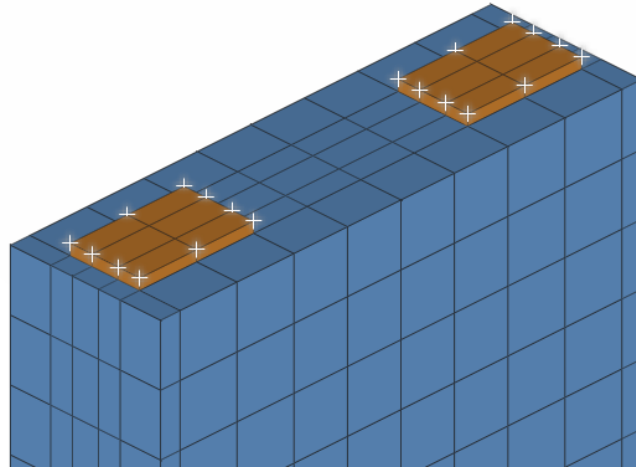
Open Circuit Voltage curve definition

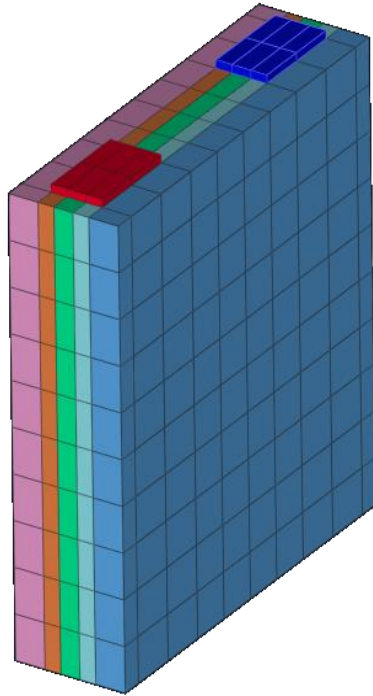




Isopotential Definition

Isopotential Connection Definition





Negative Current Collector

Anode

Separator

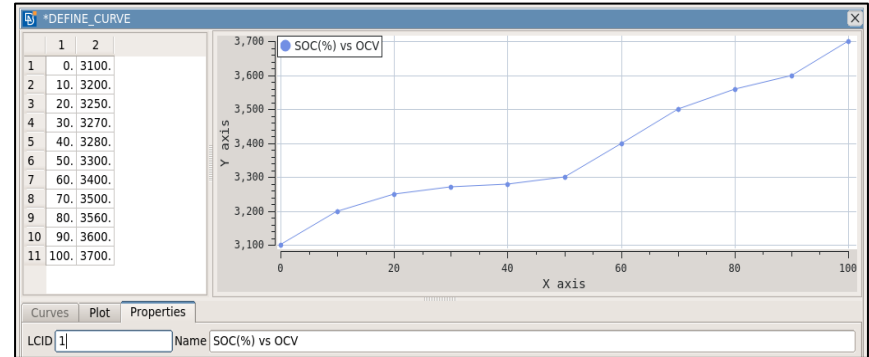
Cathode

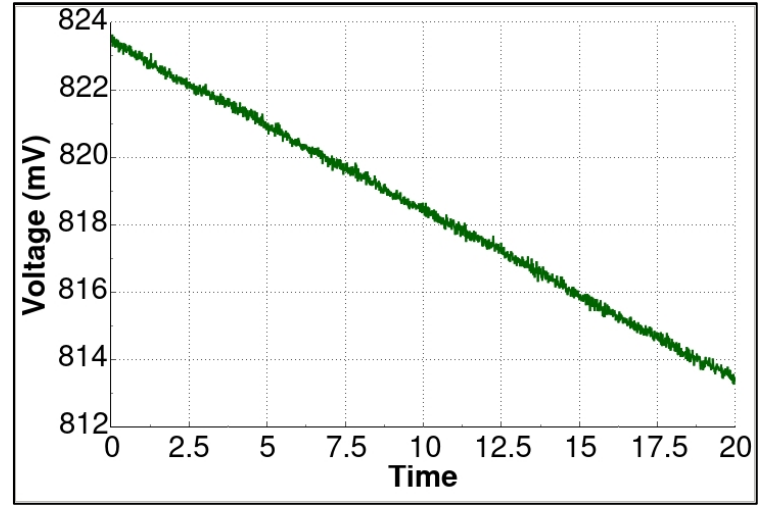
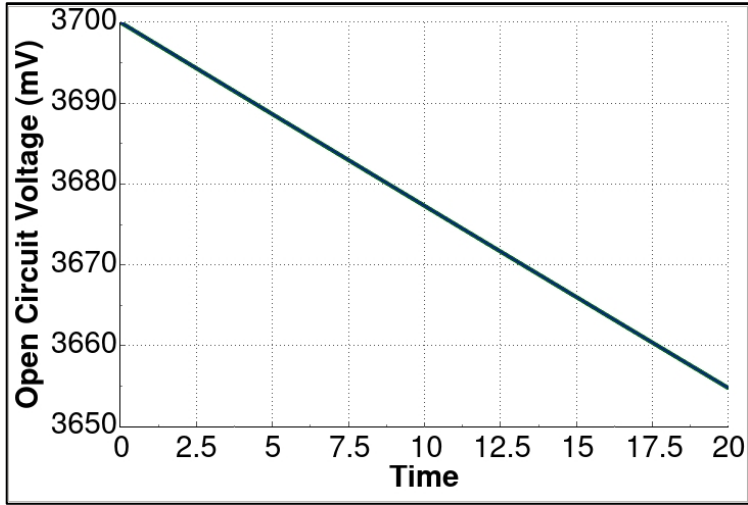
Positive Current Collector

Multimaterial setup

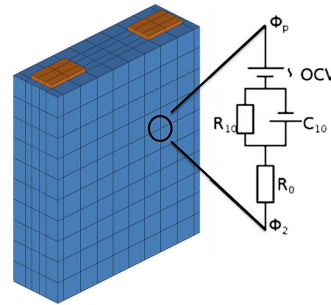
Electromagnetic properties definition

Open Circuit Voltage curve definition





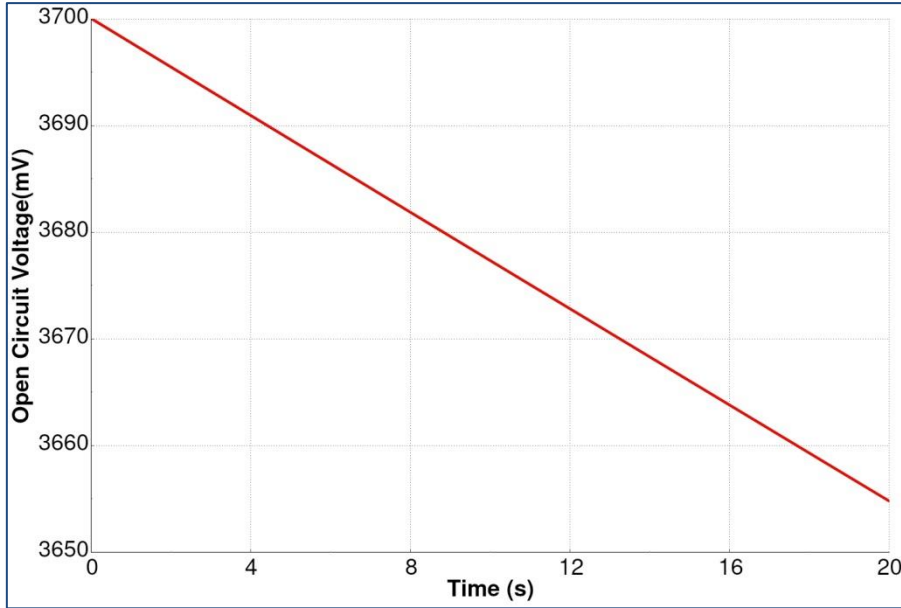
Open Circuit



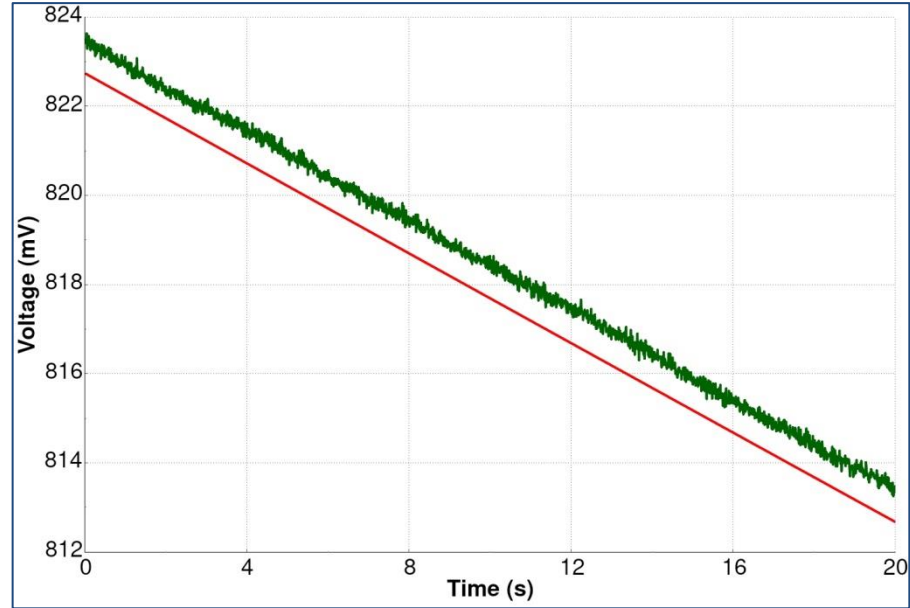
Closed Circuit



Distributed Randles

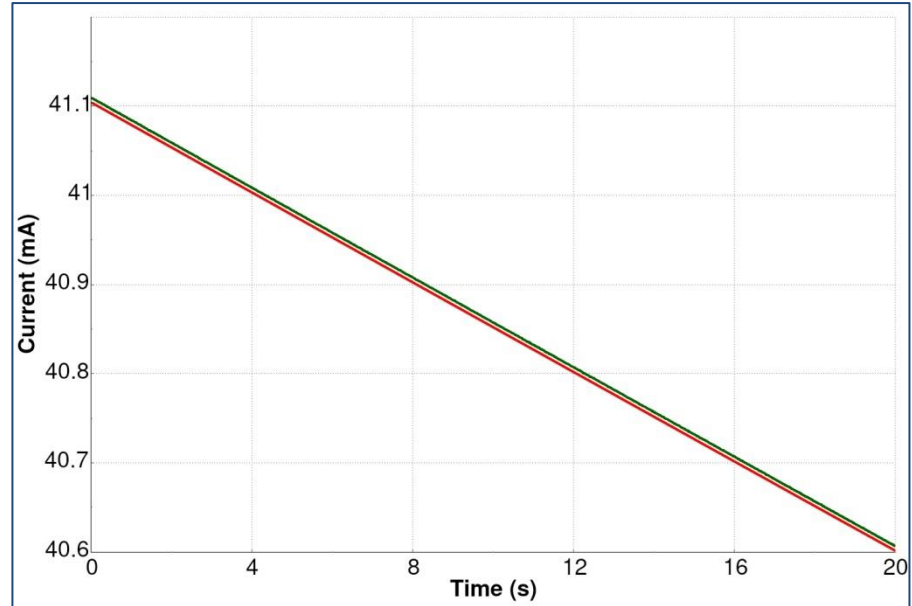
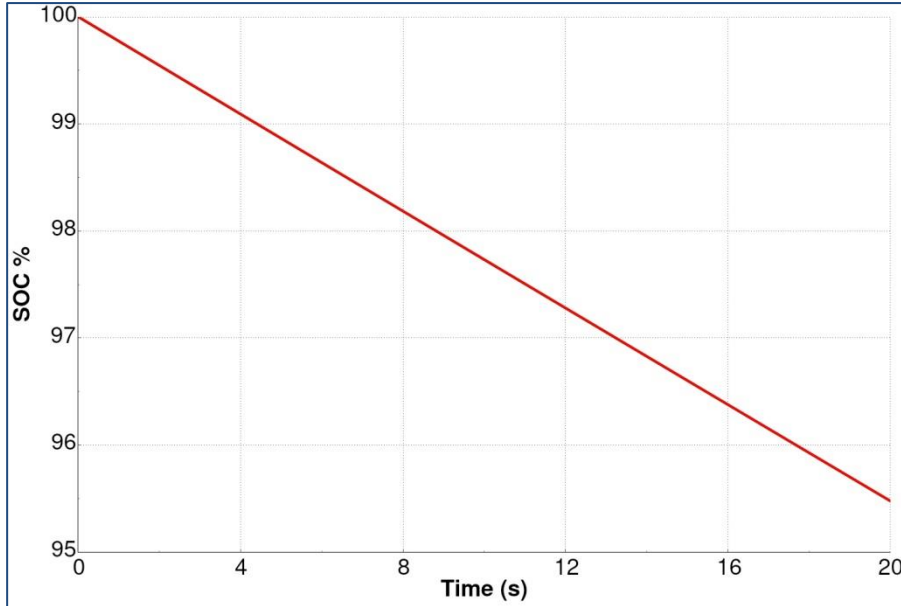


BatMac Randles

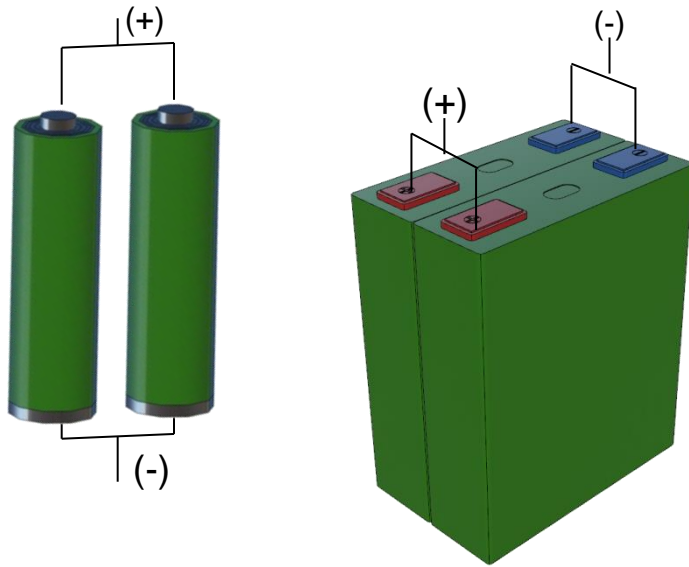


**Distributed Randles**

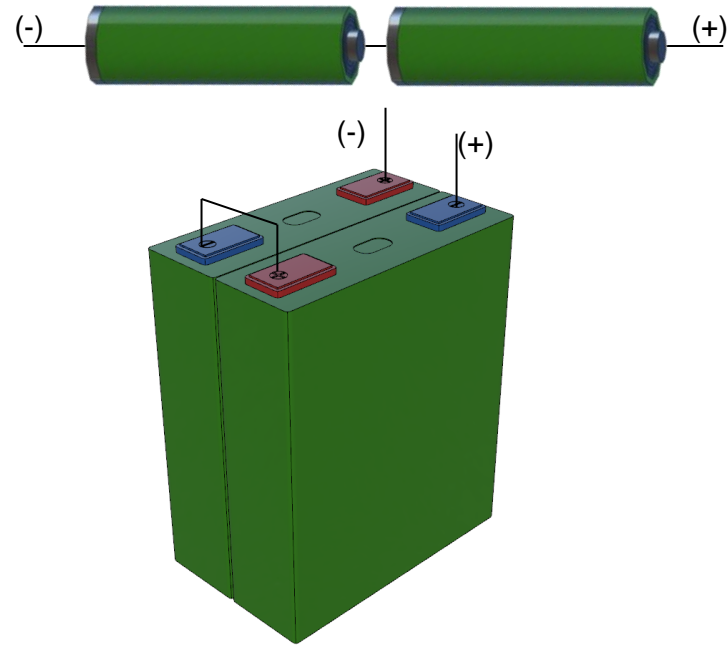
**BatMac Randles**



### Parallel Setup

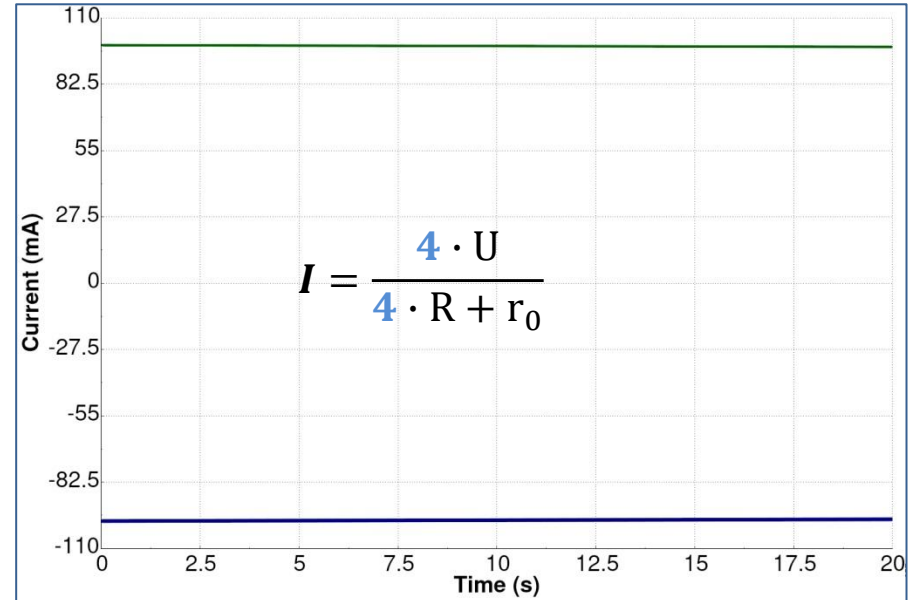
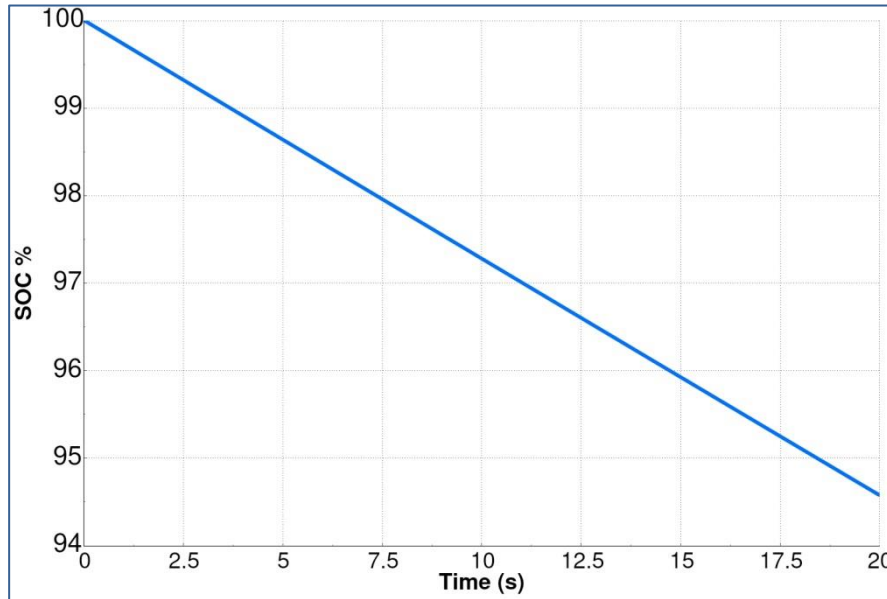


### Serial Setup



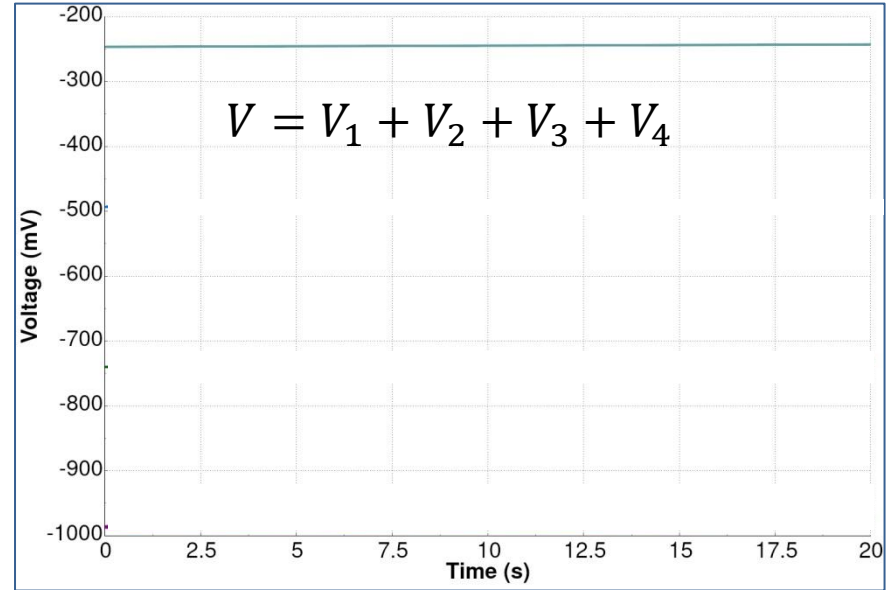
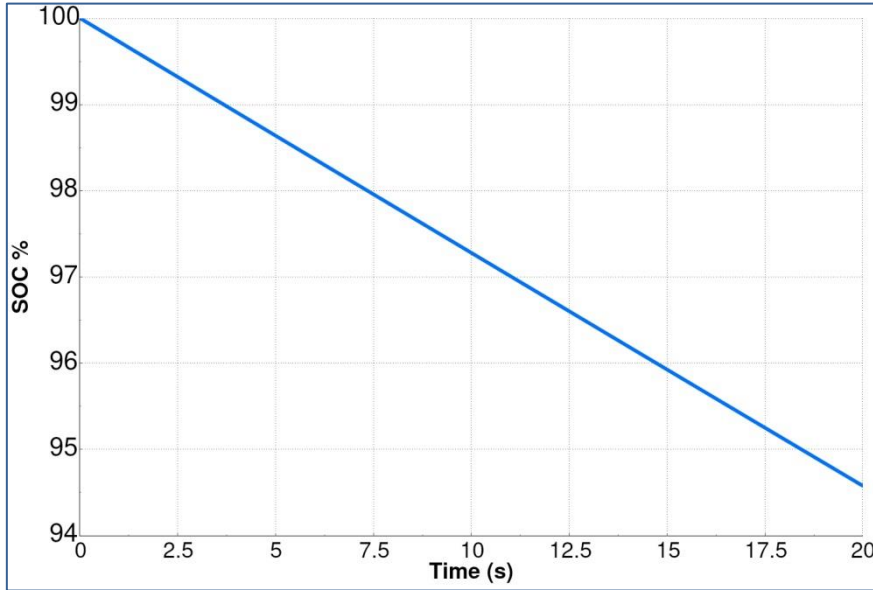


## 4 Batteries Connected in Parallel

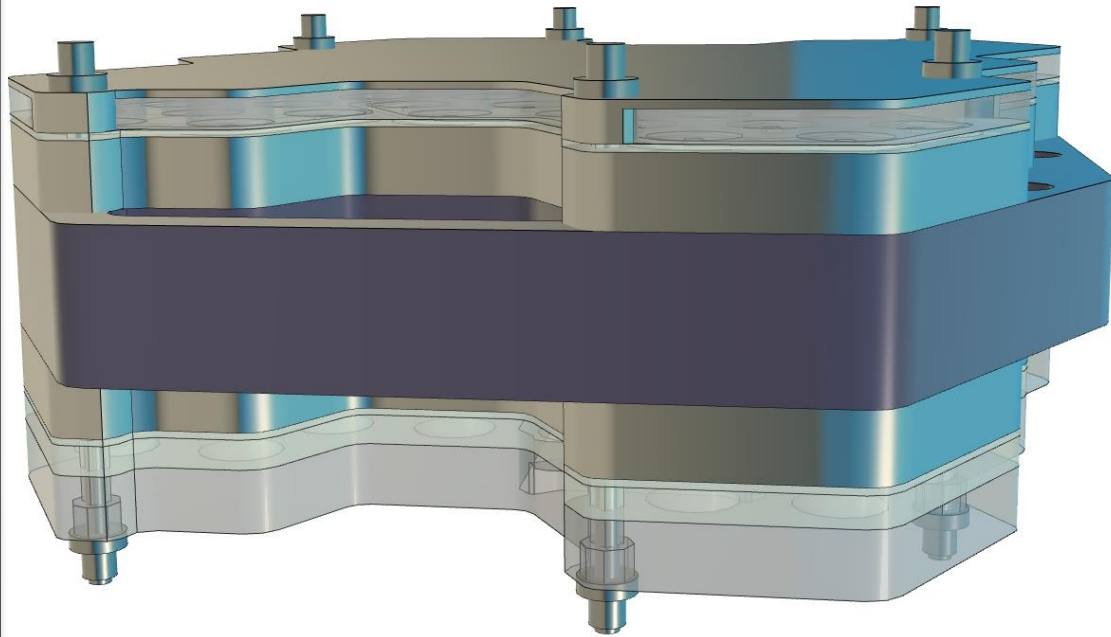


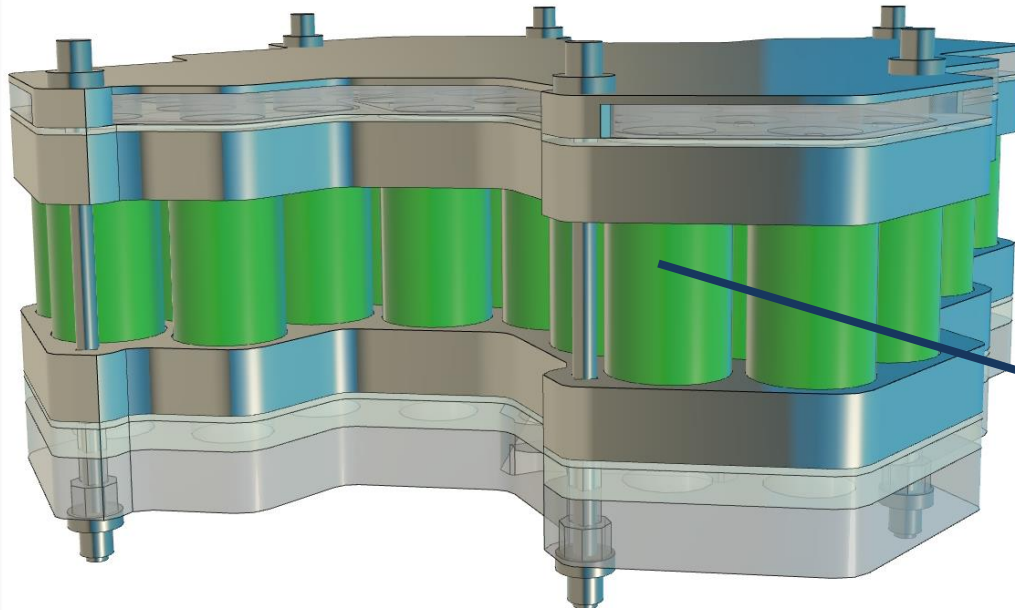
$$V = V_1 = V_2 = V_3 = V_4$$

## 4 Batteries Connected in Series



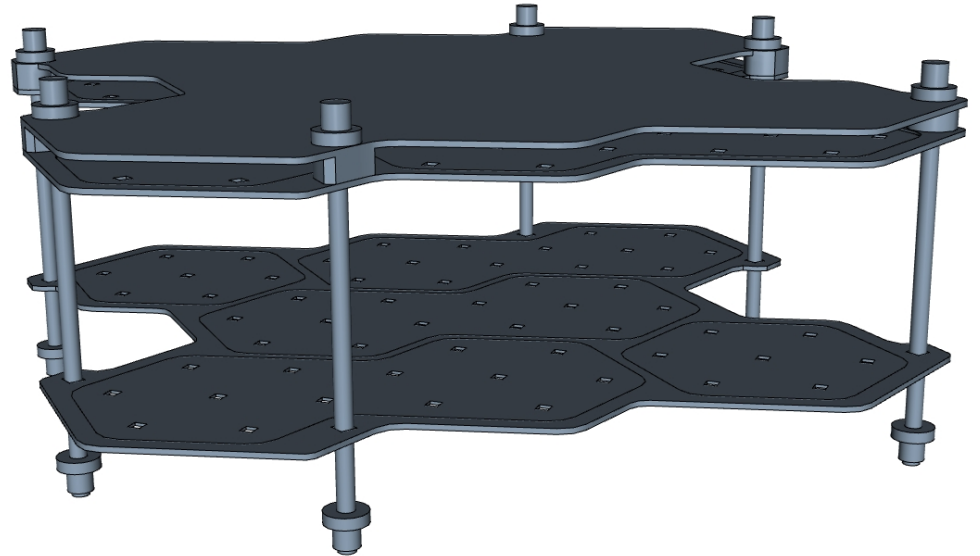
$$I = I_1 = I_2 = I_3 = I_4$$





**Materials**

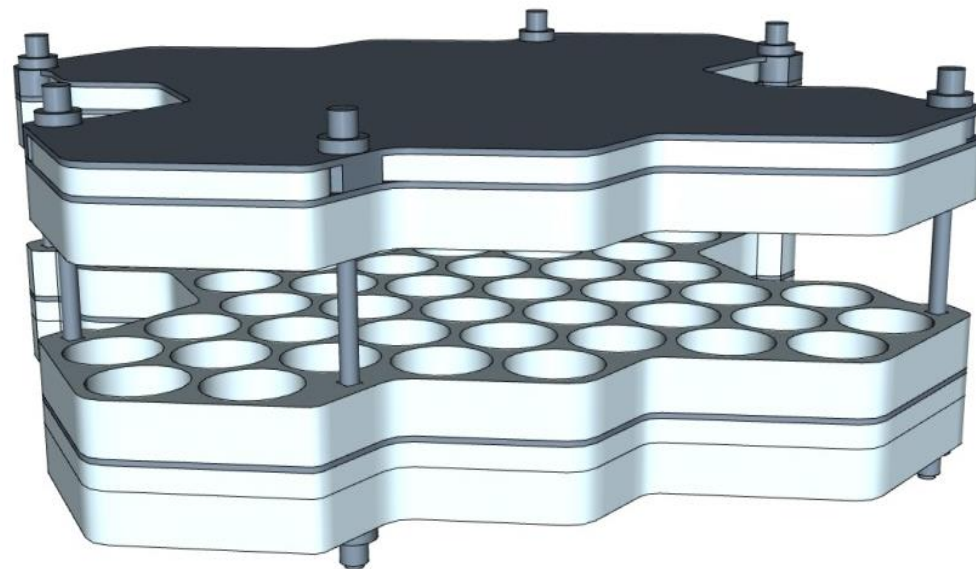
Stainless Steel 306



### Materials

Stainless Steel 306

Aluminum Alloy

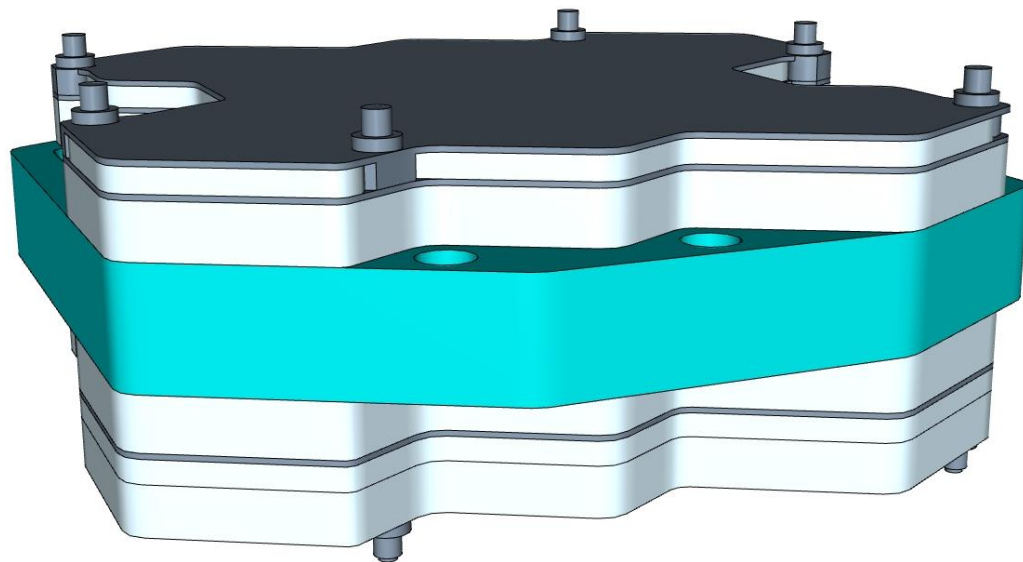


**Materials**

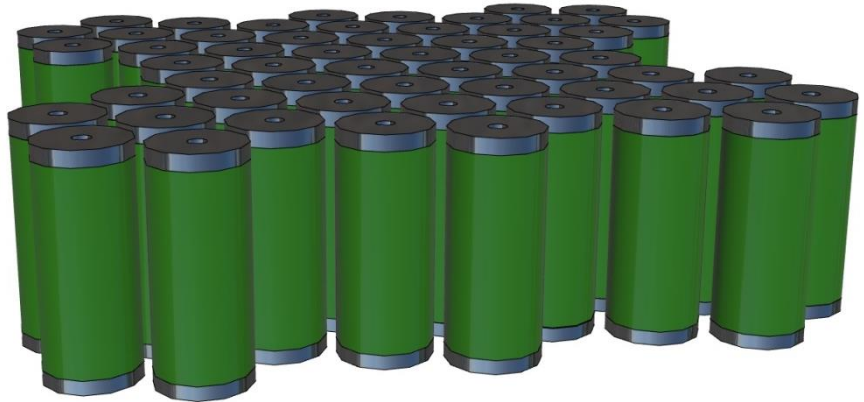
Stainless Steel 306

Aluminum Alloy

PVC Coating



Materials
Stainless Steel 306
Aluminum Alloy
PVC Coating
Nickel-Plated Steel 9%





Internal Short Function

Compression Test

if Stress > Max Value

Internal Short R=0



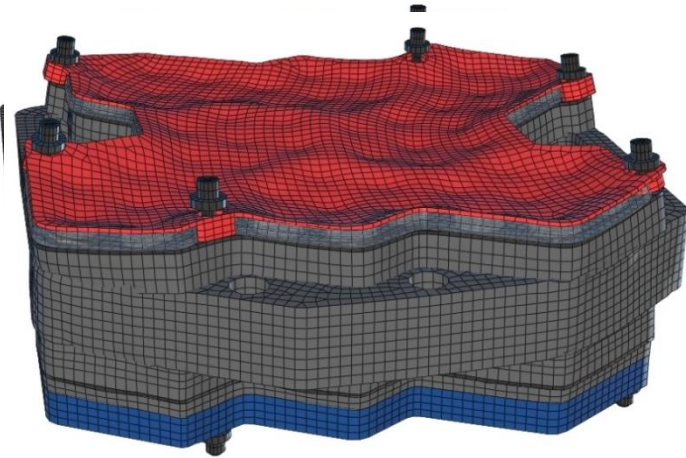
Exothermal Reaction Function


Voltage Drop

if Voltage < Min Value

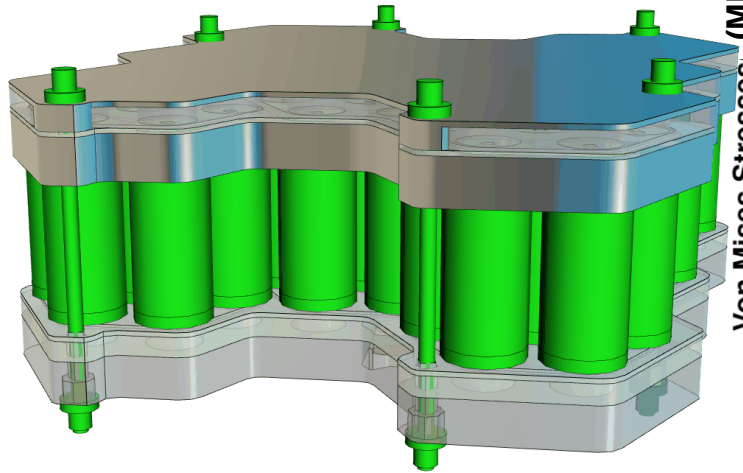
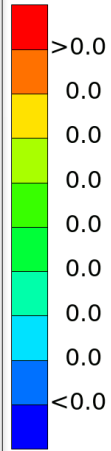
Exothermal Reaction



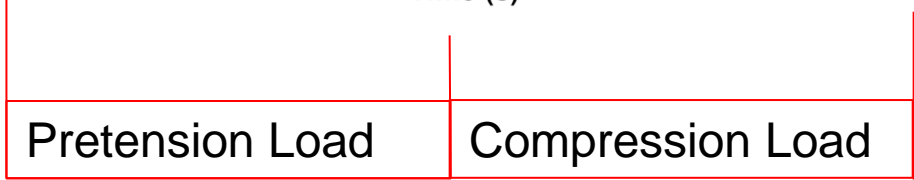
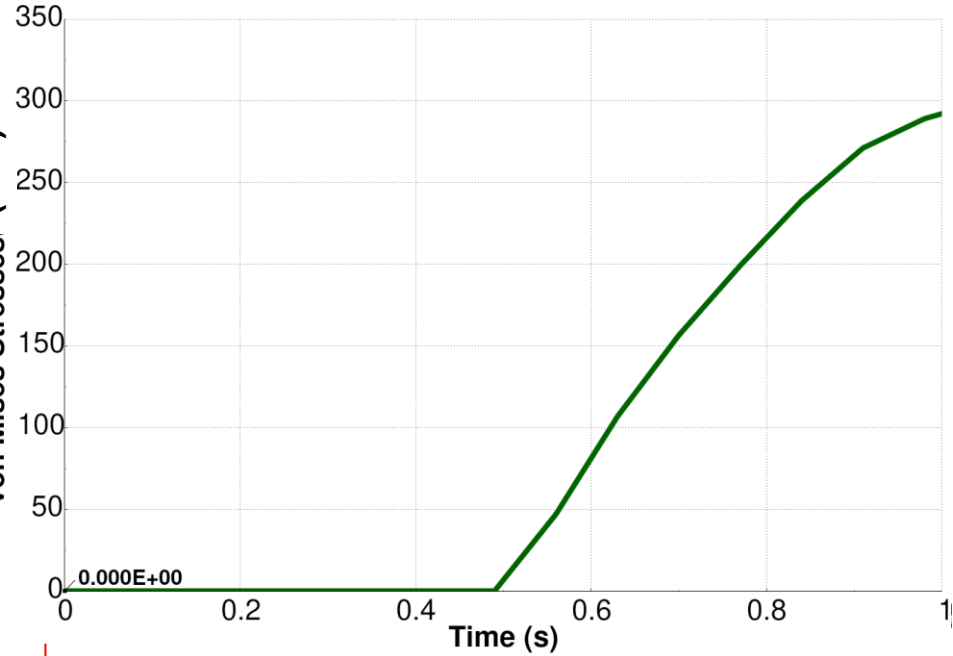


MODEL STATS		 <b>ANSA</b> <small>PRE PROCESSOR</small>	
Element Types		Hexa/Pentas	
Number of Elements		61139	
Simulation Time (sec)		2	
Solving Time (h)		72	
Number of CPUS		12	
Solver Type		Double Precision EM Solver	

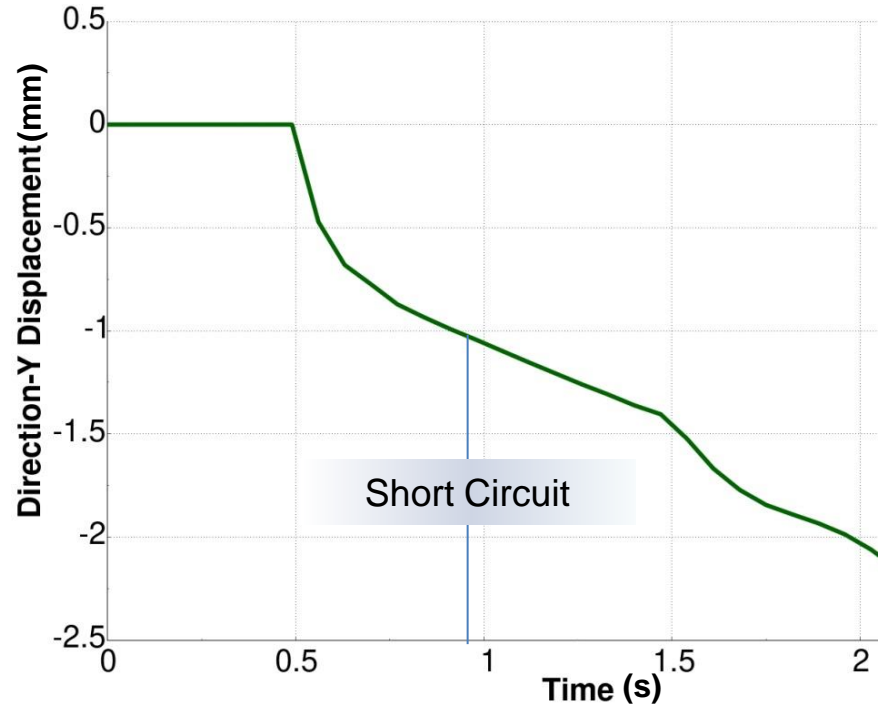
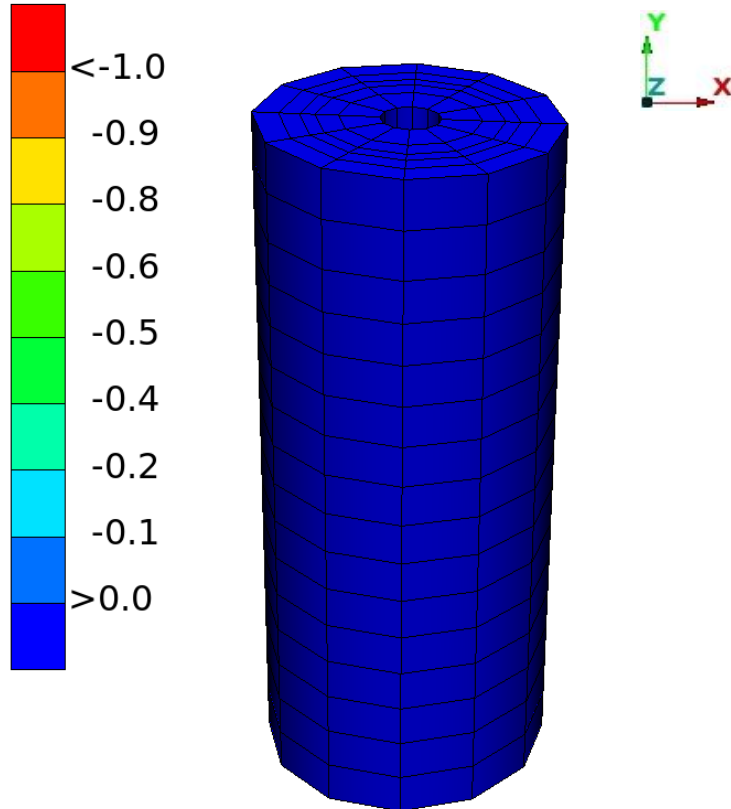
Stresses, Von Mises



Von Mises Stresses (MPa)

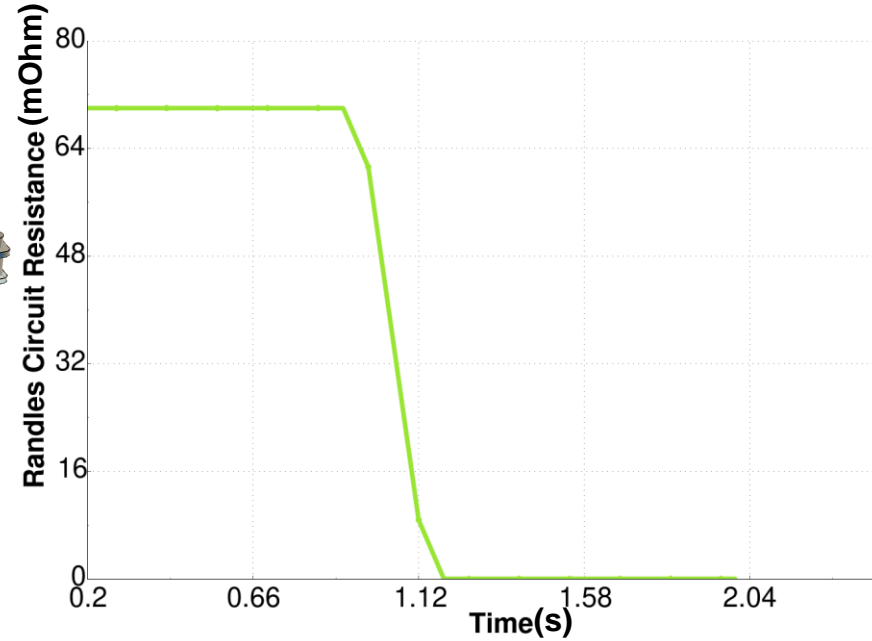
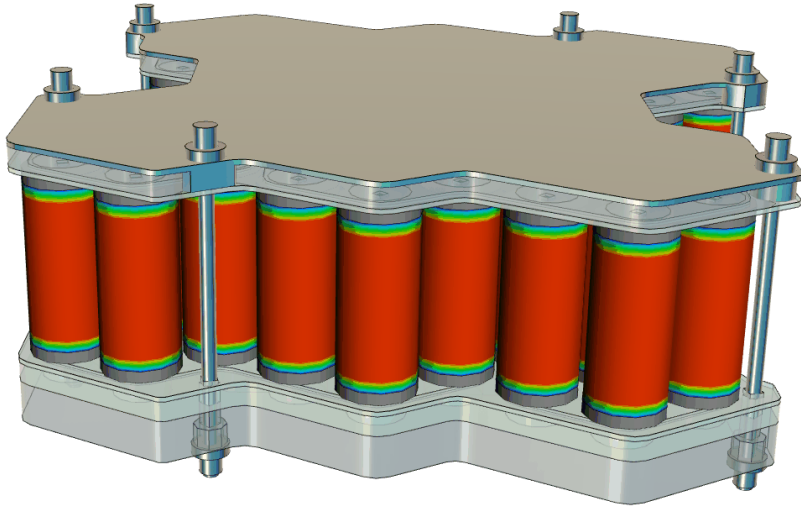
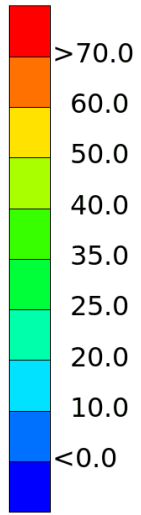


Displacements, Direction-Y

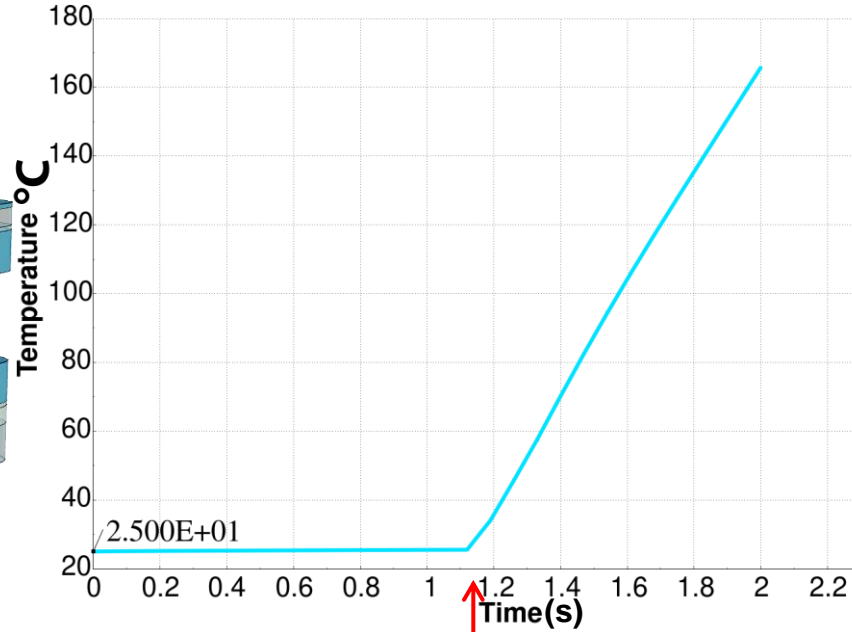
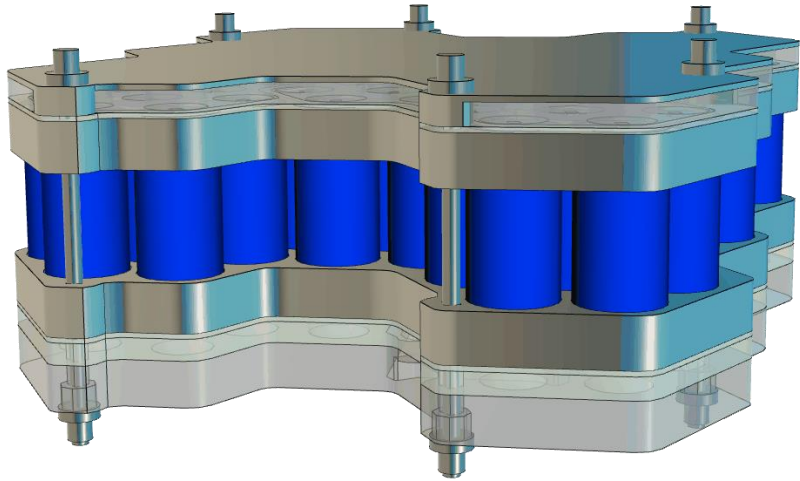
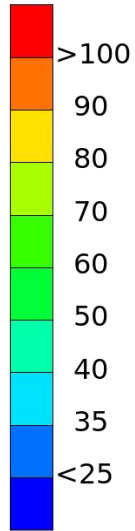


\*Chao Zhang et Al. 'A representative-sandwich model for simultaneously coupled mechanical-electrical-thermal simulation of a lithium-ion cell under quasi-static indentation tests'

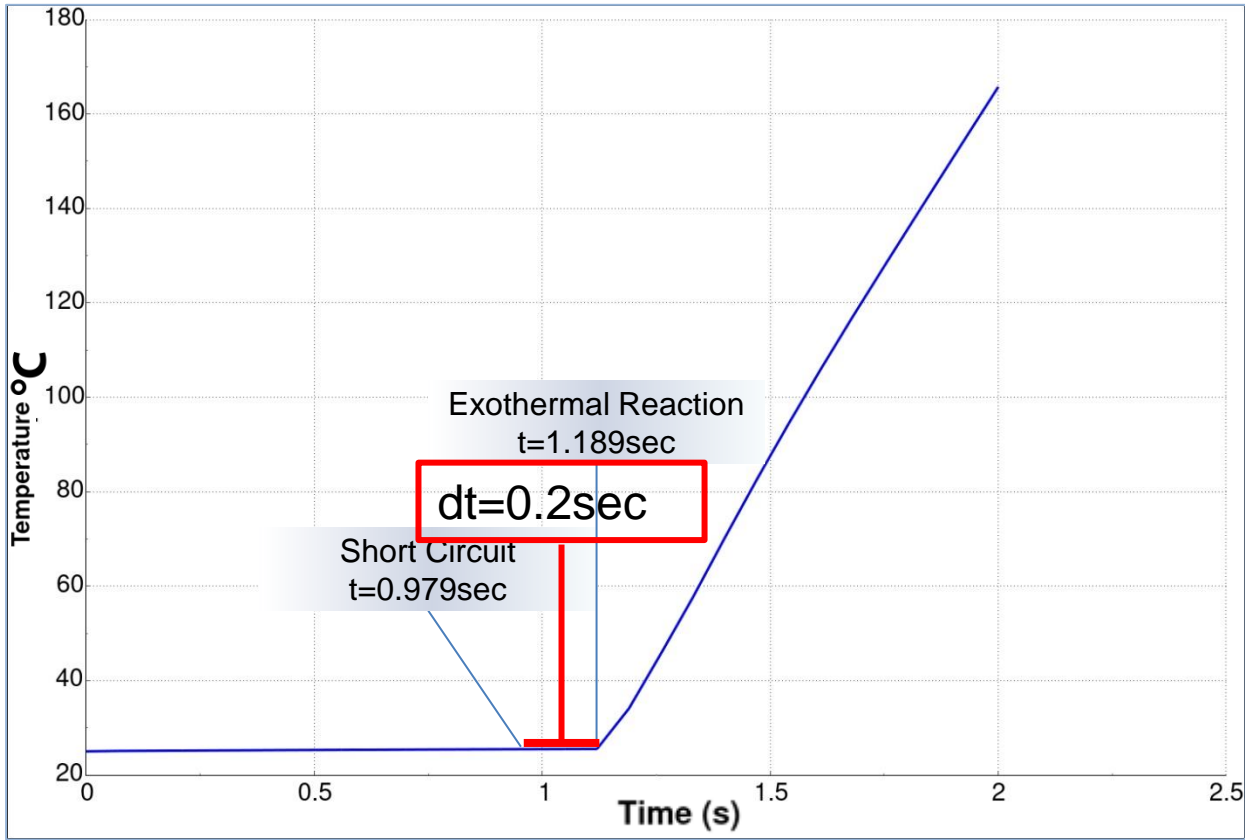
Randles Circuit Resistance



Temperature (Celcius)



Exothermal Reaction Starting Point



Rising electromagnetic simulation needs

Complete package to simulate batteries

Coupled simulations are possible

Support of wide range of post-processing results





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