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Design Optimization of Bulk Capacitor

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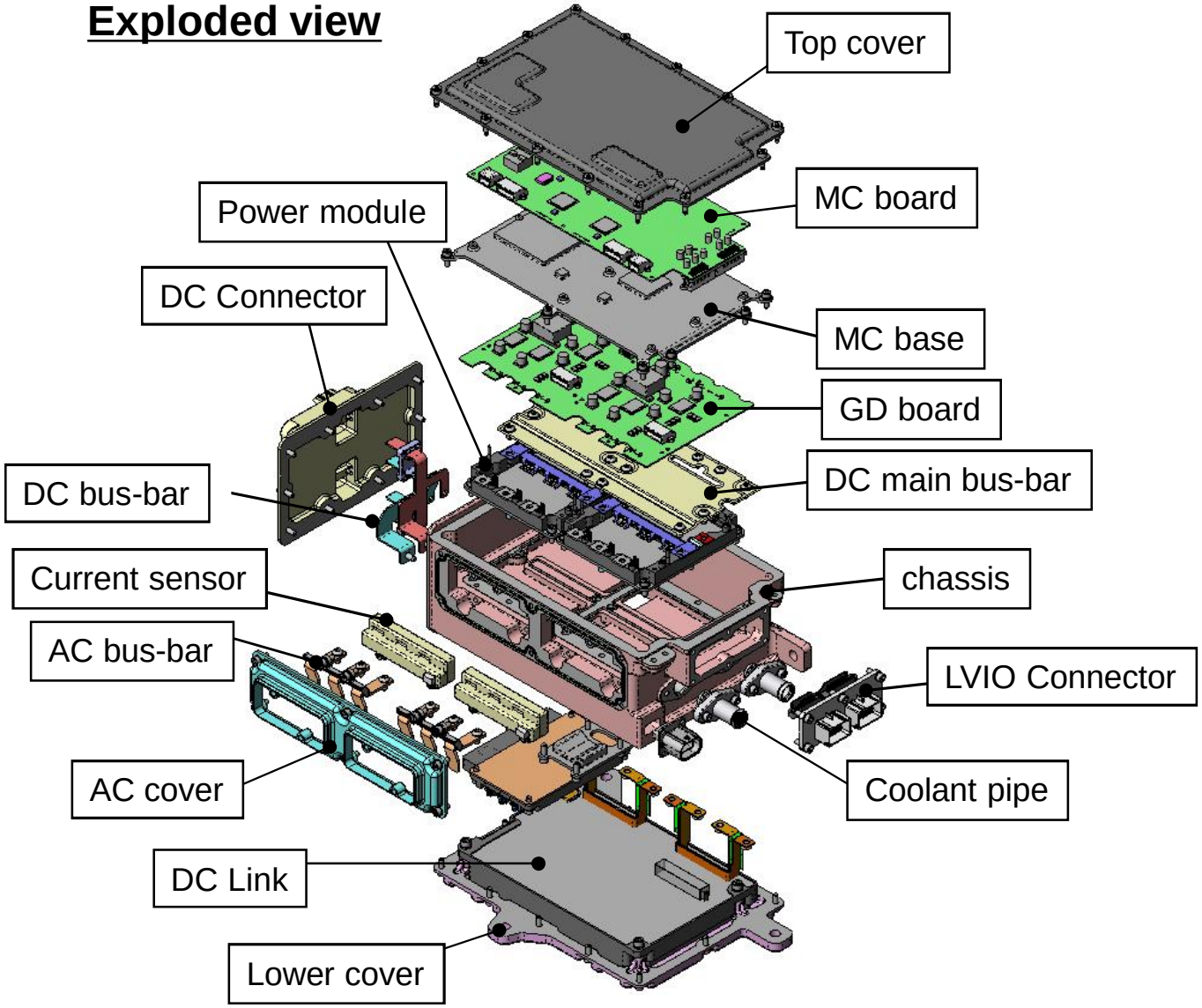
Introduction

- Fundamental Parts of Power Inverter
  - Visual BOM
- What is Bulk Capacitor ?
  - Definition / Function
  - Visual BOM / Types
- Design Requirement of Bulk Capacitor
- Validation Requirement of Bulk Capacitor
- Conclusion

Fundamental Part of Power Inverter

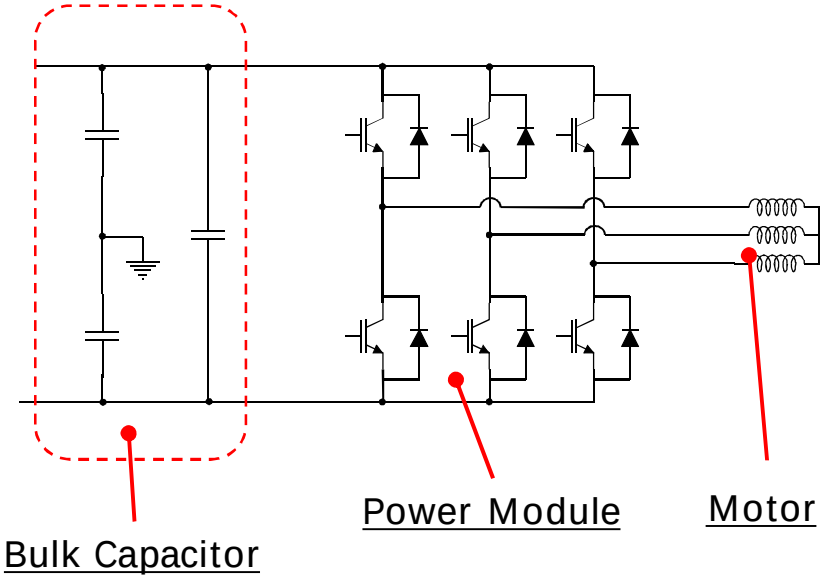
Exploded view



Bulk Capacitor – Definition / Function

Definition

Bulk Capacitor is combination of capacitors which have different design purpose. It is called as DC Link, since basic function is filtering of DC flow. Y-Capacitor, X Capacitor and bus bars are located inside Power Inverter under certain Purpose.

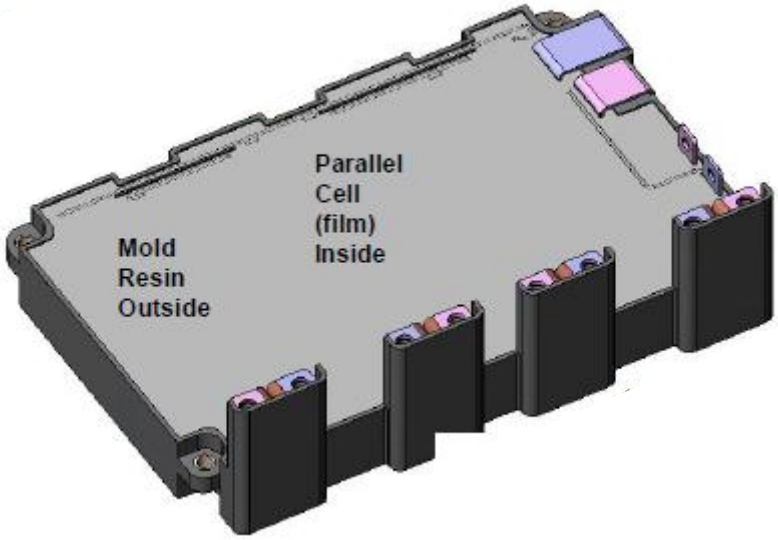


Bulk Capacitor – Definition / Function

Function

Bulk Capacitor, DC Link is used to prevent ripple currents from reaching back to the power source, and to smooth out DC bus voltage variations.

Capacitors are also used to protect semiconductors such as IGBTs.



Bulk Capacitor – Visual BOM / Types

Visual BOM of Bulk Capacitor

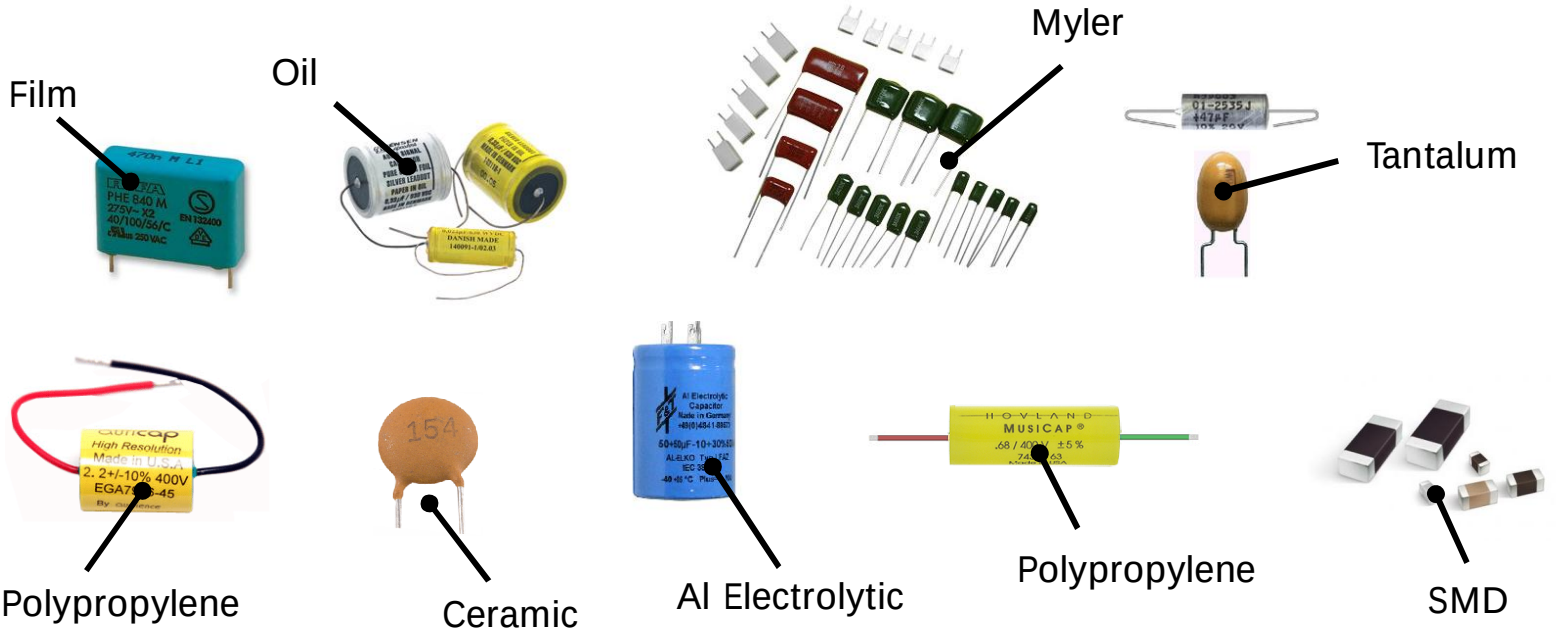
Exploded View

To be added

Bulk Capacitor – Visual BOM / Types

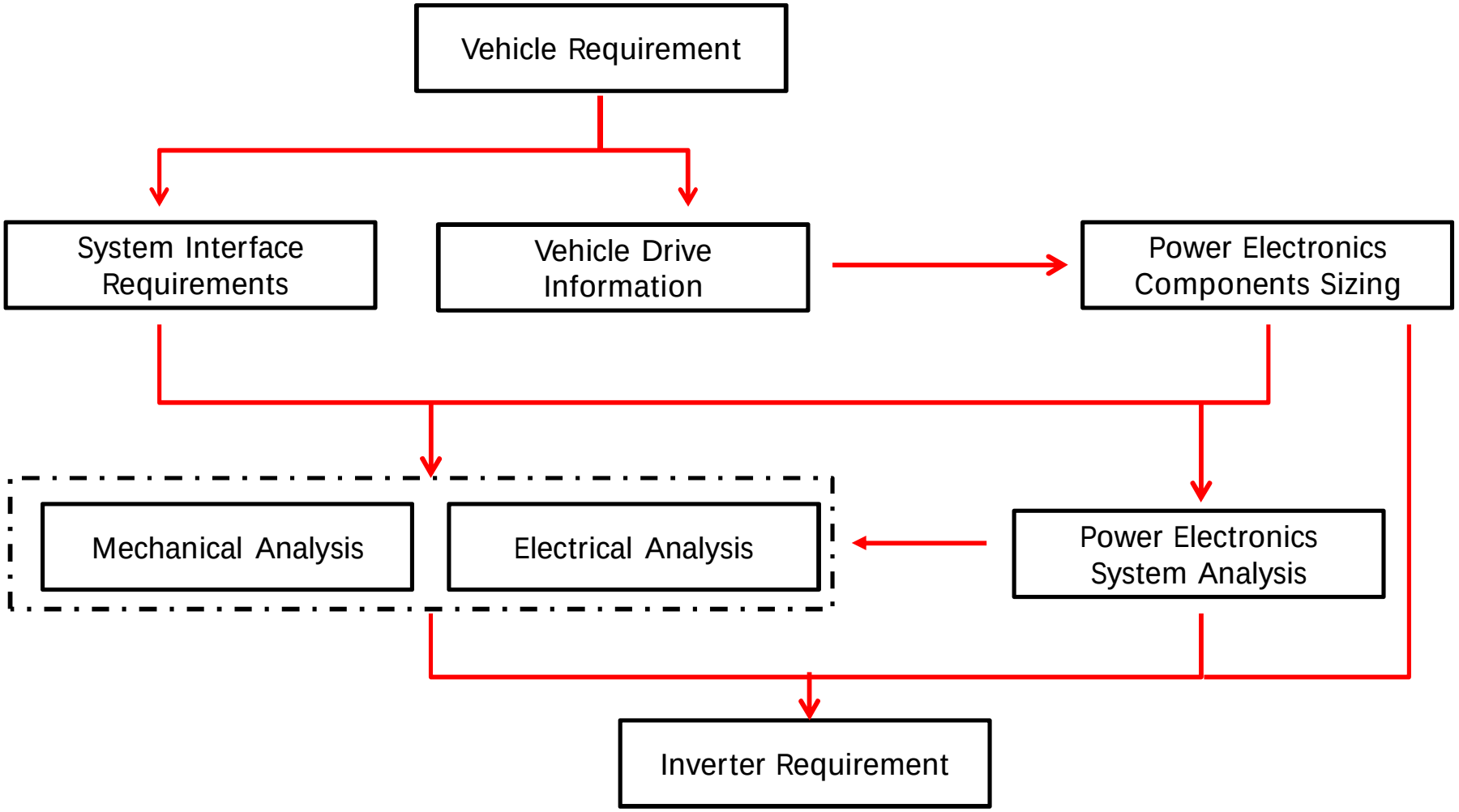
Types of Capacitors

	Size	High Freq.	Thermal Performance	High Voltage	High Capacitance	Life cycle	Cost
Al - Electrolytic Capacitor	Very Good	Bad	Bad	Good	Very Good	Bad	Very Good
Ta - Electrolytic Capacitor	Very Good	Good	Good	Normal	Normal	Good	Normal
Ceramic Capacitor	Good	Very Good	Bad	Normal	Normal	Very Good	Bad
Film Capacitor	Bad	Very Good	Good	Very Good	Good	Very Good	Bad



Design Requirement

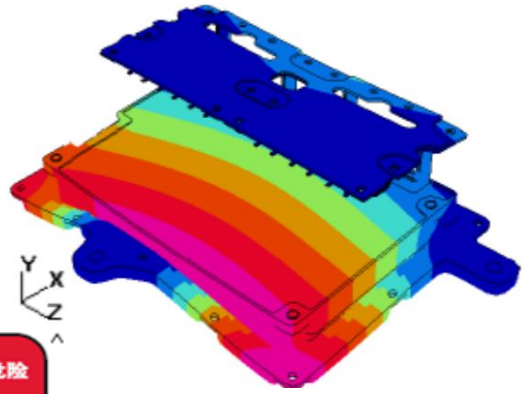
Power Inverter Design Process



Design Requirement

<u>System Interface Requirement</u>

- Voltage, Power Requirement
- Temperature(Ambient, Coolant – liquid or air)
- High Voltage Safety
- Security Requirements
- Electro-Magnetic Compatibility



<u>Vehicle Drive Information</u>

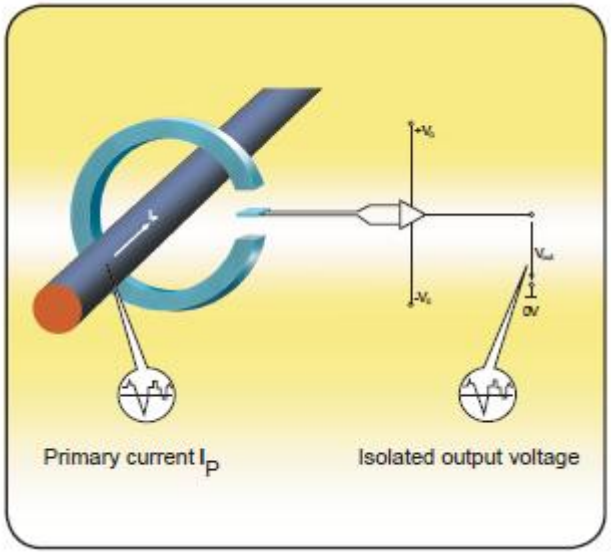
- Durability Requirement
- Thermal performance
- Fuel Economy target
- Torque Requirement

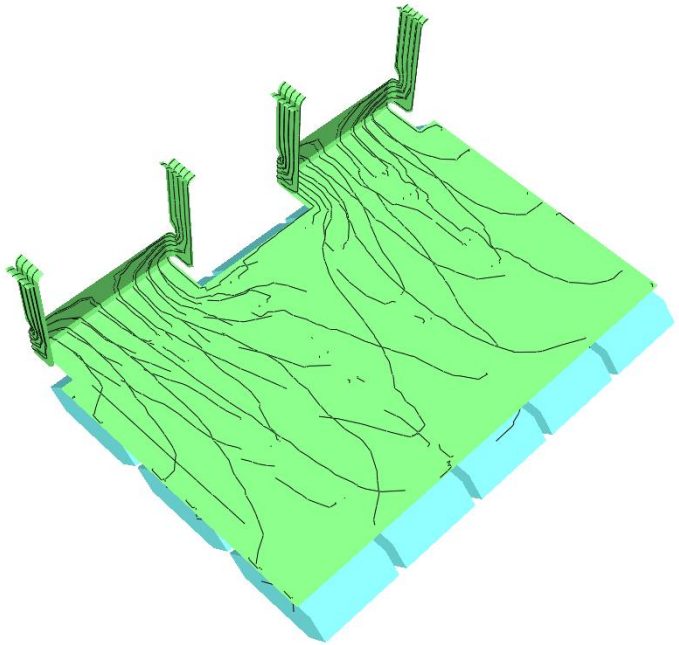
Design Requirement

Power Electronics Component Sizing

- AC Phase Current Case Scenarios
  - Number of Motors
  - Motoring & Generating
- Define Battery Voltage Range

- AC Phase Current Information
  - Peak & Continuous
  - Total & Max Duration
- Battery Voltage information
  - Peak & Continuous

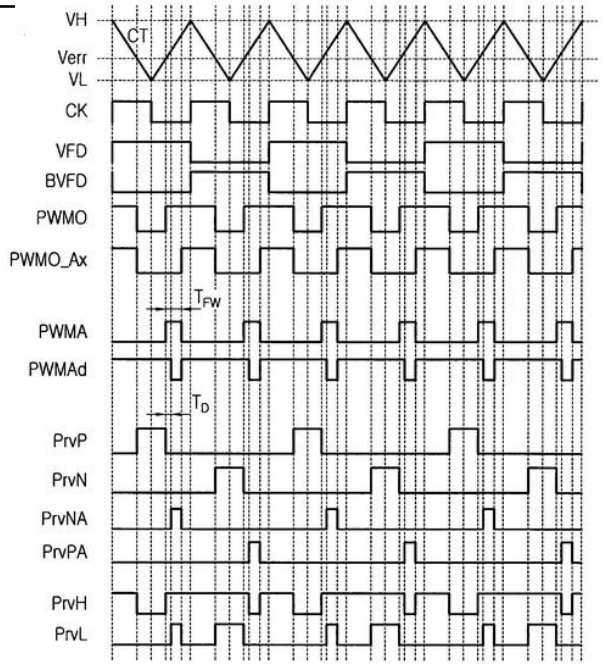


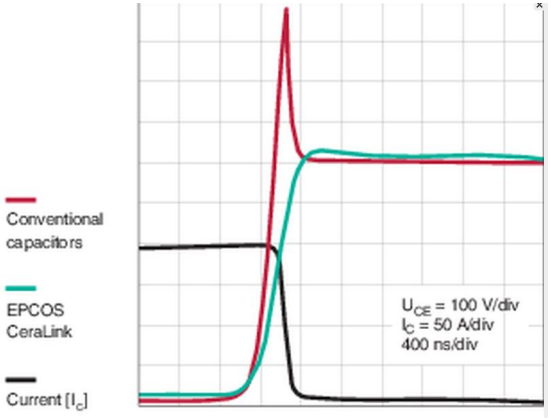


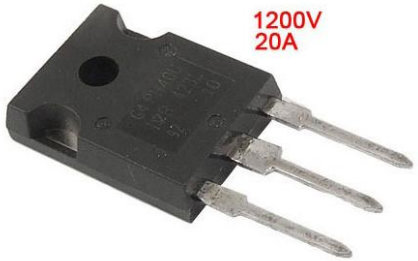
Design Requirement

Mechanical & Electrical Analysis

- PWM Frequency Profile
  - Ripple Requirement
  - PWM Algorithm
- Power Module Selection
  - Loss Parameters
  - Thermal Impedance
  - Number of Motors
  - Motoring & Generating
- Define Battery Voltage Range
- AC Phase Current Information
  - Peak & Continuous
  - Total & Max Duration
- Battery Voltage information
  - Peak & Continuous



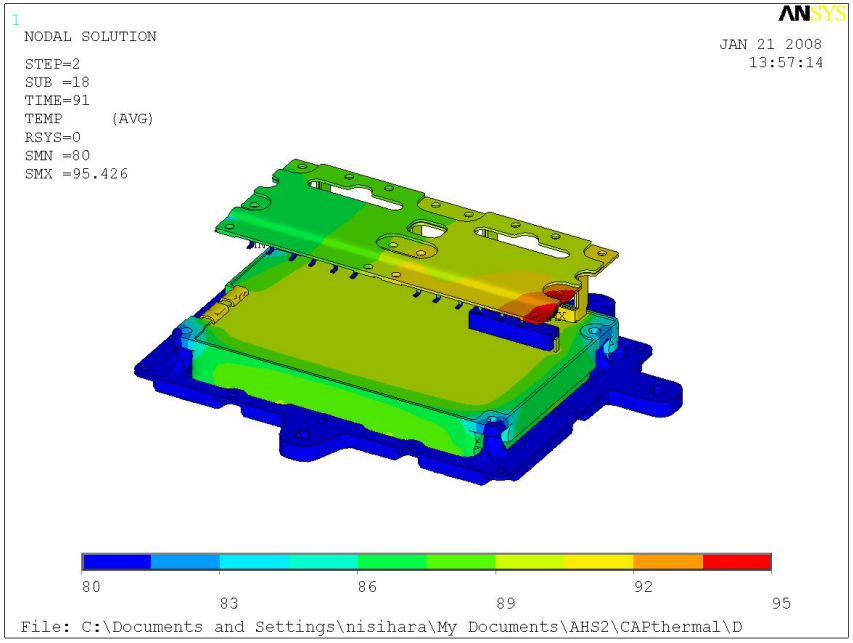


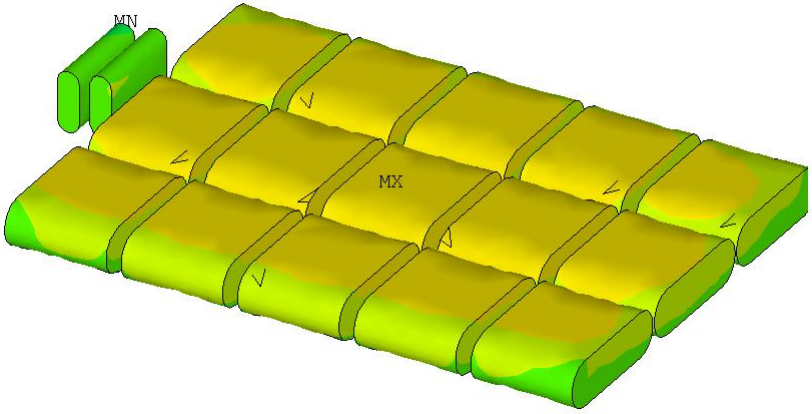


Design Requirement

Design Bulk Capacitor based on Analysis - 1

- Capacitance with Tolerance
  - Capacitance change over temperature variation
  - End of Life Capacitance
  - ESR/ESL
  - Y-Cap Capacitance
- DC Voltage Rating
- Operating Voltage
- Max Operating Voltage

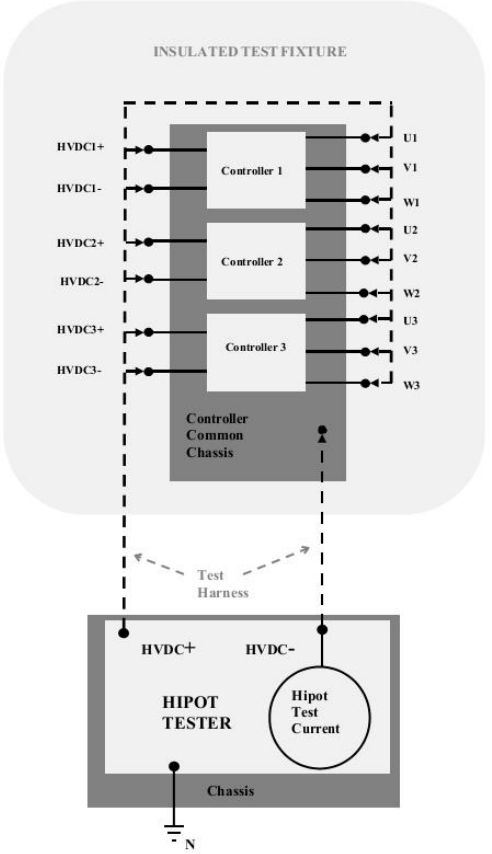




Design Requirement

Design Bulk Capacitor based on Analysis - 2

- Hi-Pot
- Isolation Resistance
- Charge/Discharge Cycle over voltage variation.
- Thermal Resistance
- Cooling Method
- Vibration Profile
- Life-Cycle(Operation hours)
  - Life Curve Prediction as a function of Ripple Current and DC Voltage over Temperature
- Potting material
- Flammability Rating



Validation Requirement

Basic Check-ups

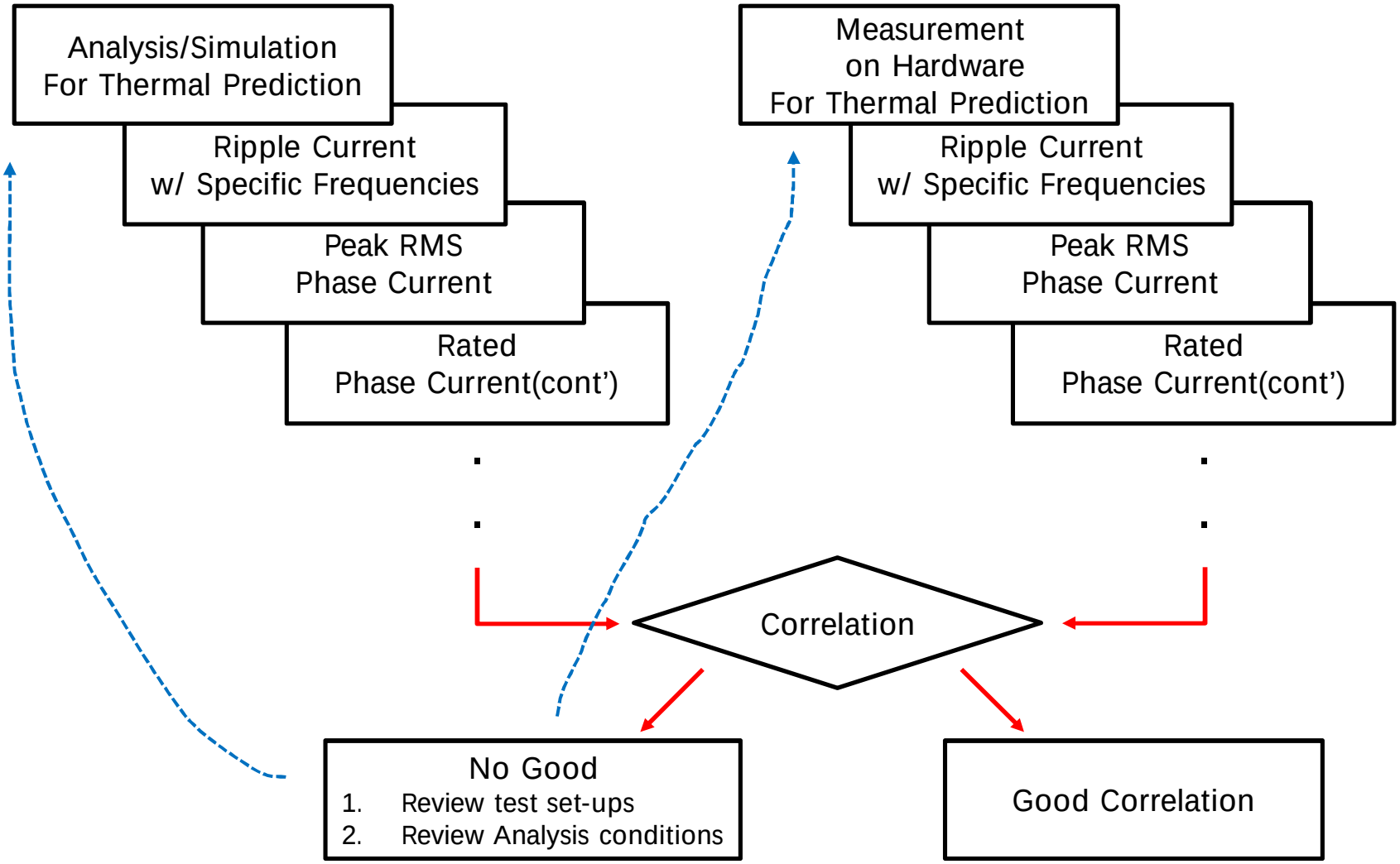
- Electrical : Capacitance with Tolerance, ESR, ESL, Impedance with specific Frequencies. Y-Capacitor's capacitance.

- Mechanical : Dimension, Materials, Thermal Performance.

Criteria	Requirement
Capacitance	≥ XX µF & ≤ XXµF
Tolerance	XX%
Test Frequency	XX kHz
Capacitance Change Over Temperature Range (XXC to XXC)	+XX% to XX%
End of Life Capacitance	≤ XX % degradation of initial capacitance value
ESR (XX C) • ESR is measured at the resonant frequency of the capacitor assembly	≤ XX mΩ
ESL (XX C) • ESL is measured at the resonant frequency of the capacitor assembly	≤ XX nH
DC Voltage Rating	XX V
Operating Voltage (nominal)	XX V
Maximum Operating Voltage	XX V
Test Voltage Between Terminals • Test time: XX sec • Test temperature: XXC	XX V

Validation Requirement

Thermal Prediction of Bulk Capacitor

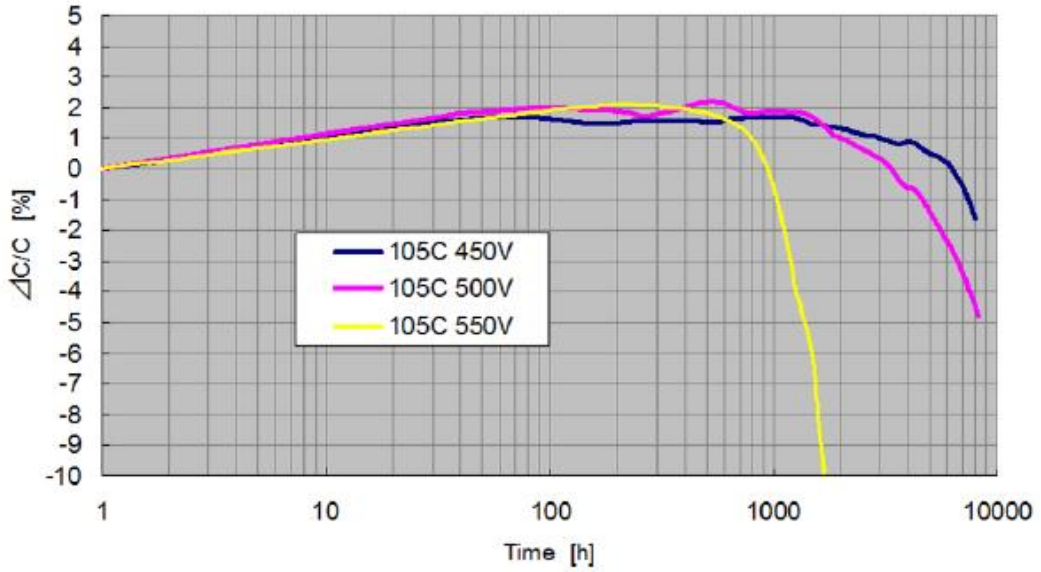


Validation Requirement

Lifetime Estimation

- High Temperature Durability test
- Capacitor life time estimation method
  - Computational method → Simulation/Analysis
  - Actual Measurement and Analysis need to be correlated.

- Capacitance Deterioration test.
  - Temperature variation with DC voltage variation.

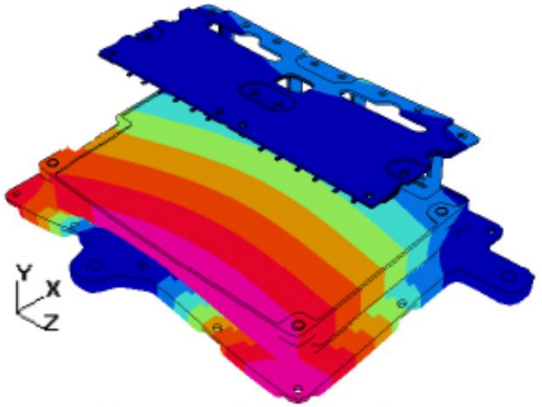


Validation Requirement – Mechanical

Vibration and Stress Analysis – Mechanical performance

Purpose : Verify Mechanical performance under certain situations electrical excitation of the capacitor (e.g. current ripple) may cause the capacitor to vibrate relative to their mounting features causing audible noise or increased mechanical stress and decreased life.

Criteria : Stack-up tolerance, specific operation scenario with specific vibration profile.

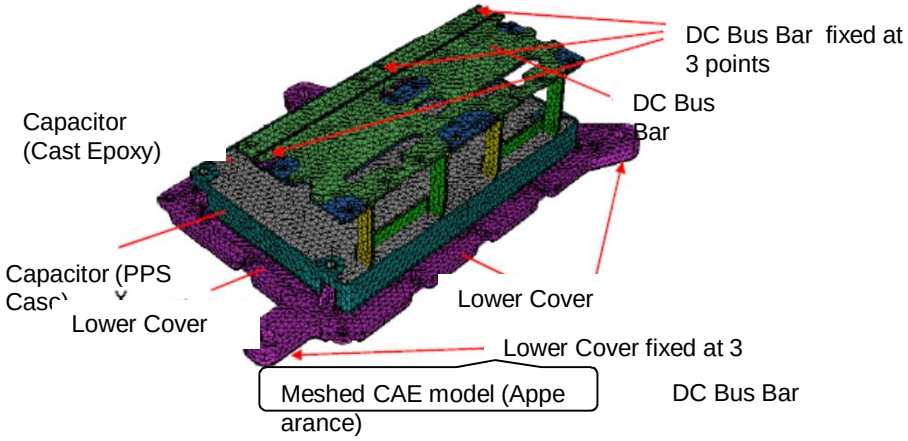


(a)1次(282Hz)：下カバー曲げモード

NVH Performance

Purpose : verify audible noise emission

Criteria : Specific scenario such as pre-charge, active discharge Operating switching frequency range, etc



Conclusion

- Bulk Capacitor should conduct DC Voltage Filtering, Noise Filtering, and Surge suppression. Capacitance can be varied over temperature, therefore Capacitor needs to be designed and verified with complicated requirements

Thank you