



CLEAR VISION

SOUND STRATEGIES

SOLID PERFORMANCE



Thermal Management in Power Electronics

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Overview

- Thermal challenges
- Design Evolution
- Forced air, natural convection, liquid, and electric cooling
- IP vs NEMA
- Heatsink design
- Designing for reliability
- The future



Thermal Objectives

- Heat is our enemy...
 - Product of component and topology inefficiencies
 - Not ‘Green’
 - Affects reliability
 - Increases material and labor cost in products
 - Additional indirect requirements on HVAC
 - Higher cost of ownership
 - A design headache !



Design Evolution

- In the past 25 years power electronics has transformed designs of secure power systems – particularly efficiencies

Conversion	Typical Old School	New Topologies
AC to DC rectification	Phase controlled SCR – Typically 75-85% efficient	Power factor corrected resonant switch-mode rectification 92%+ efficient
AC to AC UPS	Linear conversion Typically 65-75% efficient	Higher frequency PWM with IGBTs – commercial grade uses transformer-less design 90%+ efficient
DC to AC inverters	As Above	As Above
DC to DC converters	Buck / Boost conversion typically 85% efficient	Higher frequency PWM soft switched mode 92%+



Types of Cooling

Type	How applied	Advantages	Disadvantages	Outcome
Forced Air	Axial or Squirrel cage fans over heatsink	Increased power to volume ratio, economic	Mechanical devices requiring change out, prone to failure	Has become more popular as fan reliability has increased
Convected Air	Heatsink	No moving parts, simple	Requires larger heatsink and power devices	Has become less attractive due to cost
Liquid	Pumped coolant through heatsink	Best reduction in size of power assemblies	Requires pumps and heat exchangers	Generally used in special applications
Peltier (Electric)	Bi metallic thermal electric pads	Static, no moving parts	Inefficient, transports less energy than it uses	Used with micros, generally not used in power electronics



IP vs NEMA

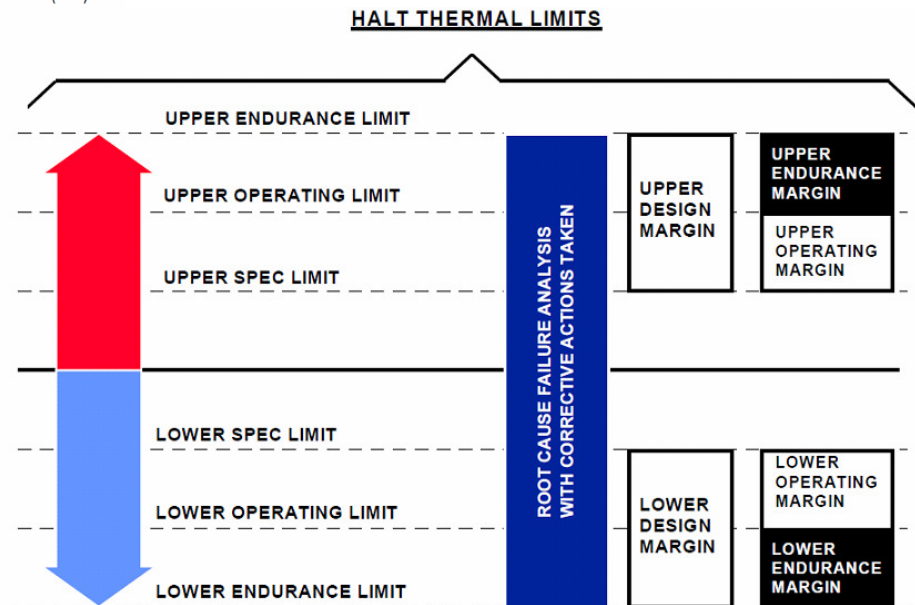
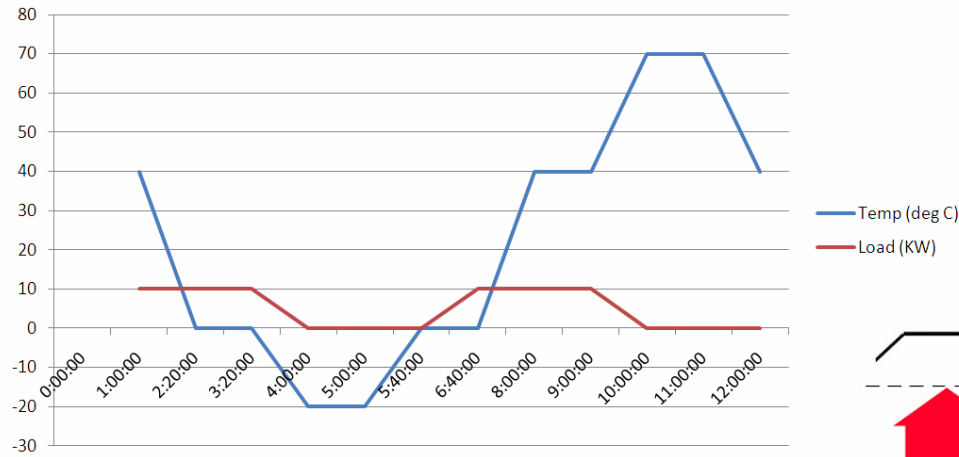
Solid #	Description	Liquid #	Description	Energy #	Description	IP	NEMA
0	No protection against contact or entry of solids.	0	No protection.	0	No protection.	IP14	1
1	Protection against accidental contact by hand, but not deliberate contact. Protection against large objects. (greater than 50mm)	1	Protection against drops of condensed water. Condensed water falling on housing shall have no effect.	1	Protects against impact of 0.225 joule. (e.g. 150 g weight falling from 15 cm height).	IP23	2
2	Protection against contact by fingers. Protection against medium-size foreign objects. (greater than 12mm)	2	Protection against drops of liquid. Drops of falling liquid shall have no effect when housing is tilted to 15 degrees from vertical.	2	Protected against impact of 0.375 joule (e.g. 250 g weight falling from 15 cm height).	IP30	3 3R 3S
3	Protection against contact by tools, wire, etc. Protection against small foreign objects. (greater than 2.5mm)	3	Protection against rain. No harmful effect from rain at angle less than 60 degrees from vertical.	3	Protected against impact of 0.5 joule (e.g. 250 g weight falling from 20 cm height).	IP55	4 4X
4	Protection against contact by small tools and wires. Protection against small foreign objects. (greater than 1mm)	4	Protection against splashing from any direction.	4	Protected against impact of 2.0 joule (e.g. 500 g weight falling from 40 cm height).	IP64	5
5	Complete protection against contact with live or moving parts. Protection against harmful deposits of dust.	5	Protection against water jets from any direction.	5	Protected against impact of 6.0 joule (e.g. 1.5 kg weight falling from 40 cm height).	IP65	6 6P
6	Complete protection of live or moving parts. Protection against penetration of dust.	6	Protection against conditions on ships' decks. Water from heavy seas will not enter.	6	Protected against impact of 20.0 joule (e.g. 5 kg weight falling from 40 cm height).	IP66	12 12K
		7	Protection against immersion in water. Water will not enter under stated conditions of pressure and time.			IP67	13
		8	Protection against indefinite immersion in water under a specified pressure.				

Key: Affect on Equipment Cooling



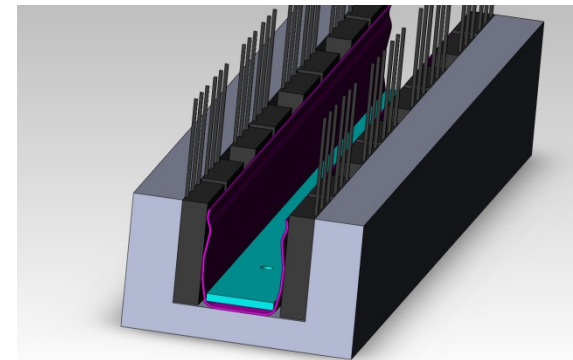
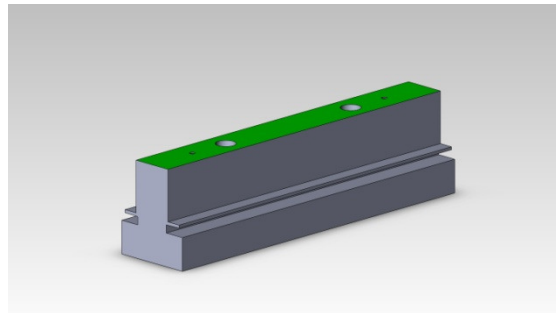
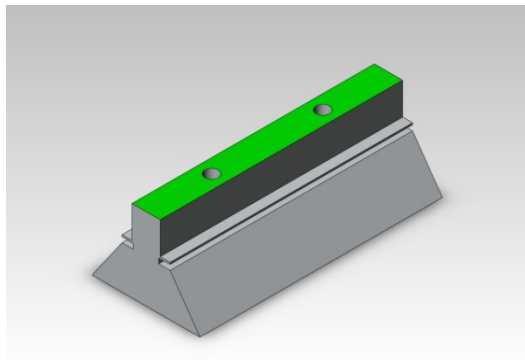
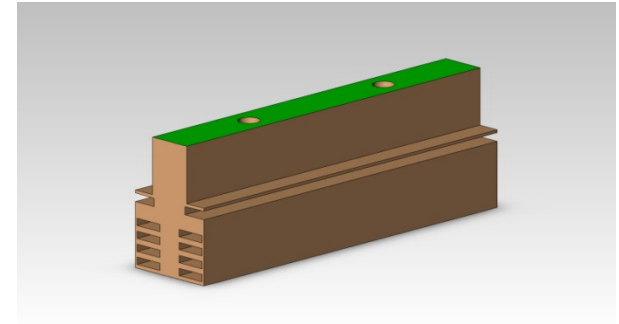
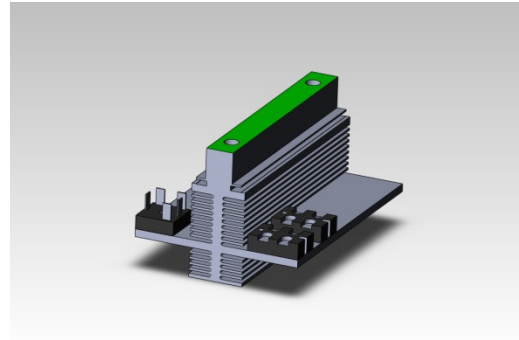
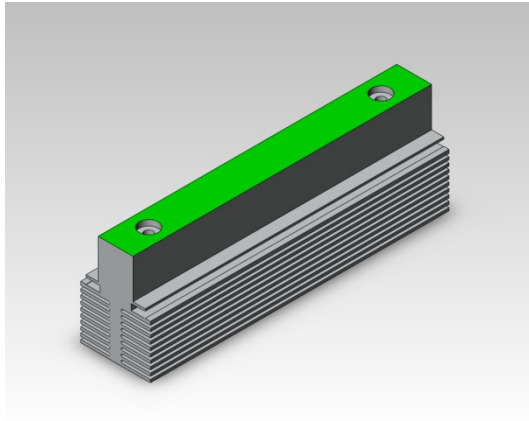
HALT Testing (DT and NDT)

Test Profile





Heatsink Design (A case study)





Typical Industrial UPS Design Criteria

- Semiconductors
 - Less than 65% of rated current
 - Less than 45 °C temperature rise
- Magnetics
 - UL Class N insulation system (200 °C)
 - VPI (vacuum pressure impregnation) system to ensure the varnish penetrates the windings and laminations to help conduct heat and reduce audible noise
 - Class B temperature limit (par 16.2) will increase cost and possibly equipment size
 - Alternative lower cost... – utilize insulation class H (180 °C) or higher with class F (105 °C) rise
- Capacitors
 - Less than 30 °C rise
 - Ripple current less than 70% of rated (for electrolytics)
- Wiring
 - Most petrochemical UPS specifications require that the UPS internal power wiring use wire with Halogen-free, flame retardant insulation with an insulation voltage rating of at least 600 Volts and 90 °C



The Future

- Silicon Carbide / Gallium Nitride Technology
 - Higher power more efficient
- Ultra Capacitors vs. Batteries ?
 - Consequences of rapid charging
- Effect of EV technology on market ?
 - Next generation in liquid cooling
- Ceramic and Polymer Heatsinks