Design & Verification of Thermal Management for SiC PV Converter

Team 13

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Project Scope

Design, build, and test a lightweight thermal management system for the Next-Gen SiC PV converter to increase the power density.

Motivation

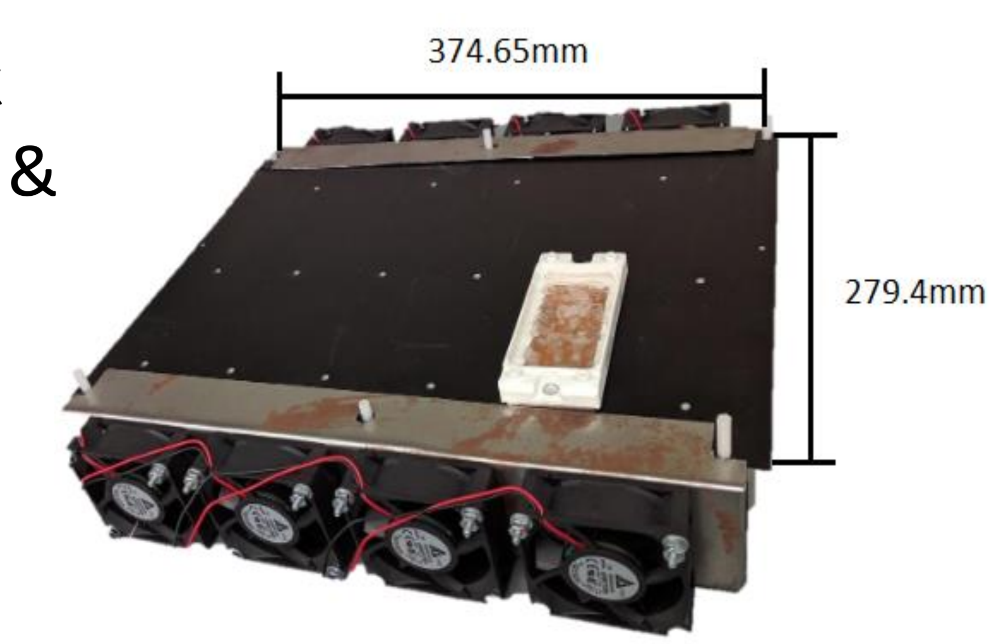
PV converters transform electrical energy with power electronic devices. The heat generated by PE devices must be dissipated to ensure safe operation. To remain competitive in the power electronics market, the next-gen PV converter's power density must be increased. The original CAPS heatsink is overdesigned and contributes nearly half of the overall system weight.

Solution Approach

Implement bi-modular pin fin heatsink to reduce size & weight using 3 methods of verification: calculations, simulations, and experimentation.

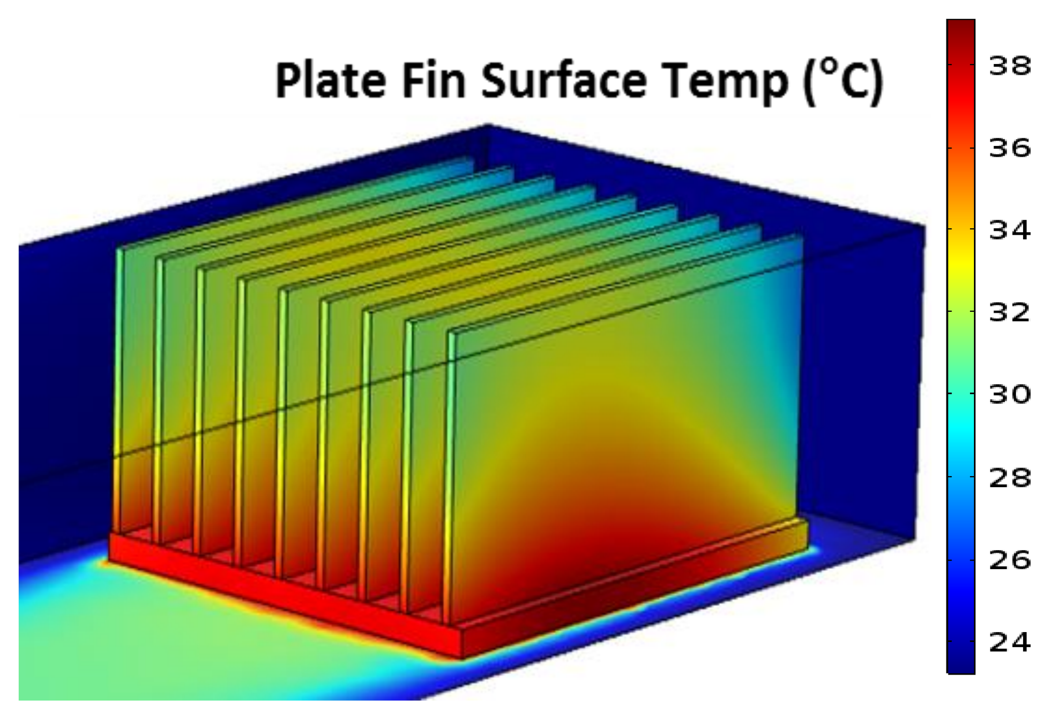
Original CAPS Heatsink

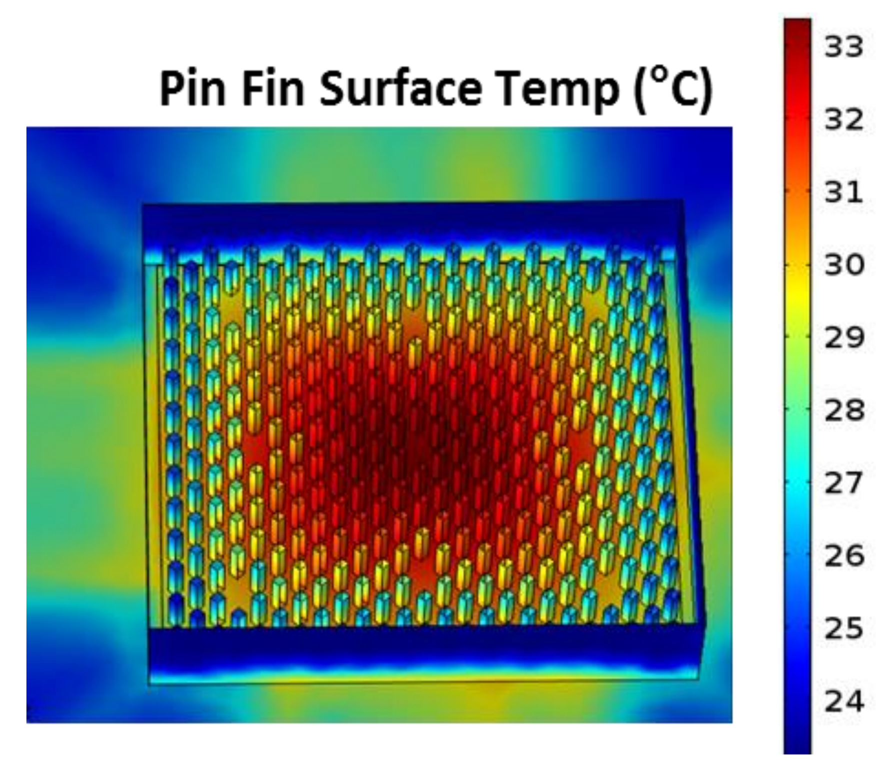
- Plate Fin Heatsink
- 8 power modules & 8 fans
- Weight: 6.45 kg
- 2.5kW/kg



Simulation Verification

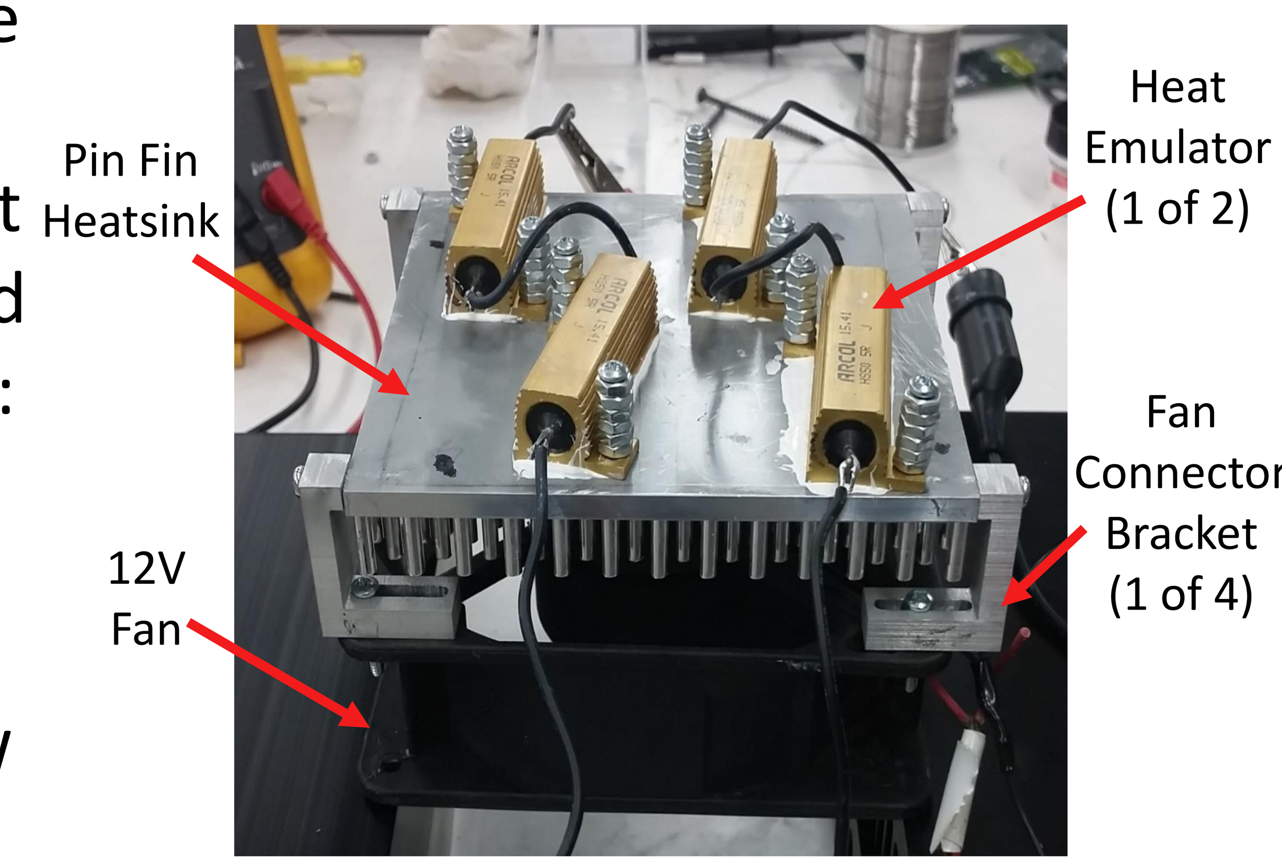
- Software: COMSOL Multiphysics
- Constructed geometry, added boundary conditions, built/refined mesh, analyzed results
- Power loss = 120 W → $T_{max} \approx$ 33-38°C
- Pin fin design was selected over plate fin due to its greater weight reduction with similar thermal results





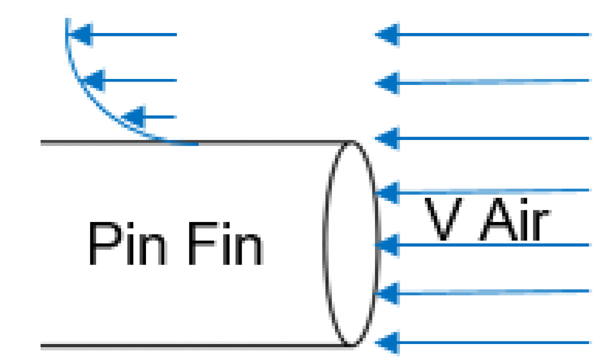
Experimental Testing

- Tested both plate fin and pin fin heatsinks
- Used 2 high power resistors in series to emulate power module heat source
- Measured temp with infrared gun at 5 points & averaged
- Natural convection: Temp > 120°C
- Forced convection: Temp ≈ 36-38°C for power of 120 W



Theoretical Analysis

- Calculated convective & conductive thermal resistance
- Important parameters:
  - Reynolds number
  - Nusselt number
  - Fin efficiency
  - Heatsink geometry

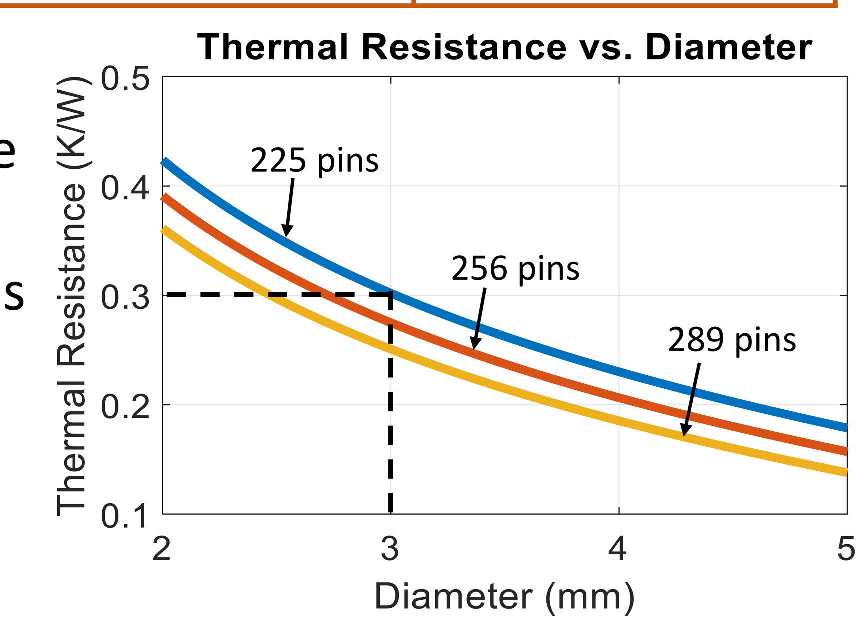


Optimization

- Weight optimization of pin fin heatsink design

Input Values	Output Values	Constant Values
• Fan Speed (0.02-0.05 m^3/s) • Pin length (5-40 mm) • Pin diameter (2-5 mm) • Number of Pins (100-300) • Pin Spacing	• Total Weight (< 0.254 kg) • Thermal Resistance (~0.3 K/W)	• Base Size (115 x 115 mm^2) • Base Thickness (4.7 mm)

- Cost of decreased weight is increased thermal resistance
- Results:
  - 15 x 15 evenly spaced pins
  - Pin Diameter = 3.0 mm
  - Pin Length = 10.0 mm
  - Weight = 211 g



Accomplishments

- Selected cylindrical pin-fin as optimized design
- Analysis, simulation, & experimentation had consistent results
- Increased power density to 6.54kW/kg
- Reduced thermal system weight by 71%