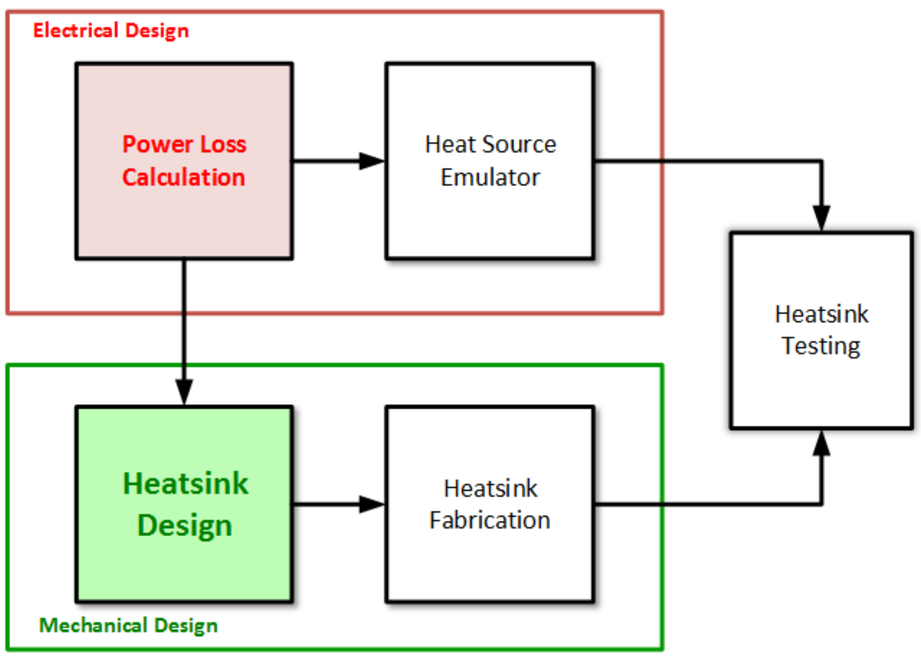
UNDERGRADUATE RESEARCH SCHOLARS

Design & Verification of Thermal Management for SiC PV Converter

PI: Dr. Hui Li
URS: James Hutchinson, Tianna Lentino, Leslie Dunn, Colleen Kidder, Melanie Gonzalez

PROJECT SCOPE

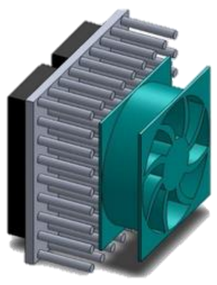
- Design, build, test, and compare advanced thermal systems for SiC power converters to increase power density
- Implement bi-modular design on pin-fin heatsink to reduce size and weight and test with heat source emulator



BACKGROUND INFORMATION

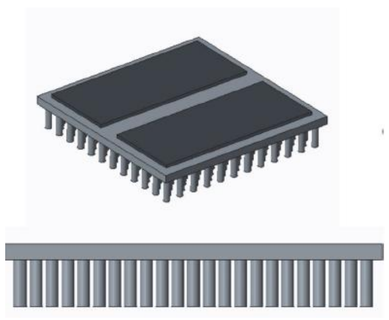
- Important to dissipate heat so that power electronic devices do not overheat which may cause failure of device
- Heatsink uses fins to dissipate heat
- Fans typically added to increase heat transfer
- Thermal resistance parameter reduces heat transfer
- Heat is caused by resistive winding in power electronic device
- Various heatsink designs are available and each offer pros and cons but only pin-fin and plate-fin will be analyzed in this project

PIN-FIN CONCEPTUAL DESIGN



$$\dot{Q} = \frac{\Delta T}{R_{total}}$$

$$Mass_{heatsink} = \rho_{Aluminum} \times Vol_{heatsink}$$



$$R_{total} = R_{conductive\_base} + R_{convective}$$

$$R_{conductive\_base} = \frac{l_{baseplate}}{k_{Aluminum} \times A_{baseplate\_cross}}$$

$$R_{convective} = \frac{1}{(N_{fins} \times \eta_{fins} \times h \times A_{fin\_surface}) + (h \times A_{unfin})}$$

$$\eta_{fins} = \frac{\tanh(m \times L_{corrected})}{m \times L_{corrected}}$$

$$h = \frac{Nu \times k_{air}}{D_{fin}}$$

$$Nu = 0.911 \times Re^{.385} \times Pr_{air}^{1/3} \quad for\ (4 \le Re \le 40)$$
$$Nu = 0.683 \times Re^{.466} \times Pr_{air}^{1/3} \quad for\ (40 < Re \le 4{,}000)$$
$$Nu = 0.193 \times Re^{.618} \times Pr_{air}^{1/3} \quad for\ (4{,}000 < Re \le 40{,}000)$$

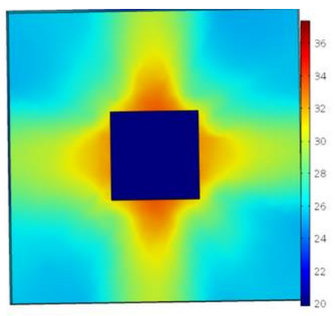
$$m = \sqrt{\frac{4 \times h}{k_{Aluminum} \times D_{fin}}}$$

$$L_{corrected} = L_{fin} + \frac{D_{fin}}{4}$$

$$Re = \frac{D_{fin} \times V_{avg}}{\nu_{kinetic\ air}}$$

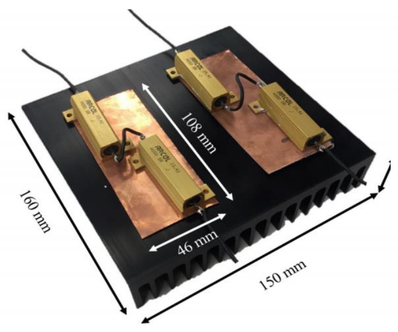
$$V_{avg} = \frac{\dot{V}}{A_{air\ flow}}$$

SIMULATION VERIFICATION

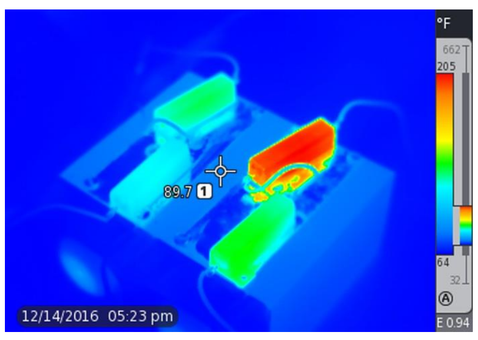


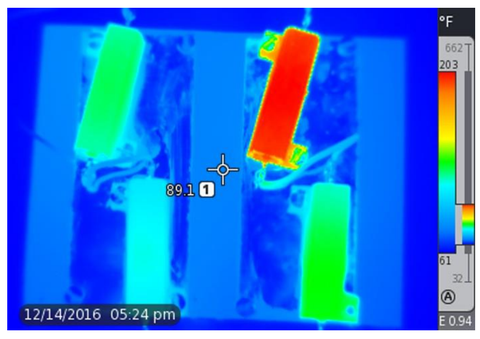
- Air inlet at top with flowrate of $2m^3$/min and outlet at sides
- Max junction temperature of 36 C
- Heat source of 120W on bottom face

EXPERIMENTAL VERIFICATION



$$\frac{T_j - T_a}{P_d} - R_{jc} - R_{ch} = R_{ha}$$





PROGRESS TO DATE

- Performed COMSOL, MATLAB, and CAD analysis for pin-fin and plate-fin heatsink designs
- Built heat source emulator and verified operation
- Heat source emulator was tested with a 2.5A, 24.5V input
- Fan mounted axially on the pin fin for optimal heat transfer
- Finished heat source testing on plate fin to determine the thermal resistance
- Initial Finite Element Analysis shows heating is concentrated directly under power module
- Heat source testing on plate fin had a 52.8˚C junction temperature

FUTURE PLANS

- Mount heat source and fan onto pin fin heatsink
- Apply input of 2.5A and 24.5V to test heatsink and heat source emulator
- Determine heatsink thermal resistance of pin fin via equation
- Perform calculations to optimize heatsink
  - Fin height, width, length, etc.

CHALLENGES

COMSOL and MATLAB analysis for pin-fin arrangement is proving difficult due to the complexities with simulation. Results up to now are erroneous and need to be corrected. The equations needed to design the optimal pin-fin heatsink are complex.