PHASE CHANGE MATERIAL TRANSIENT HEATSINK FOR POWER SEMICONDUCTOR

Final Presentation

Team 9:

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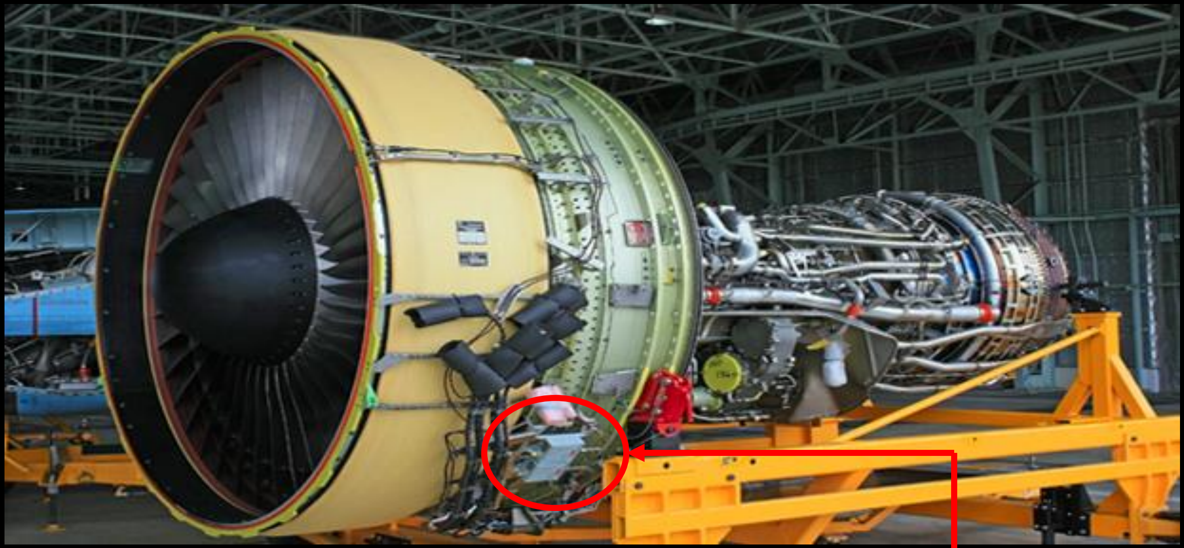
Industry Contact: Kevin Walker

OVERVIEW

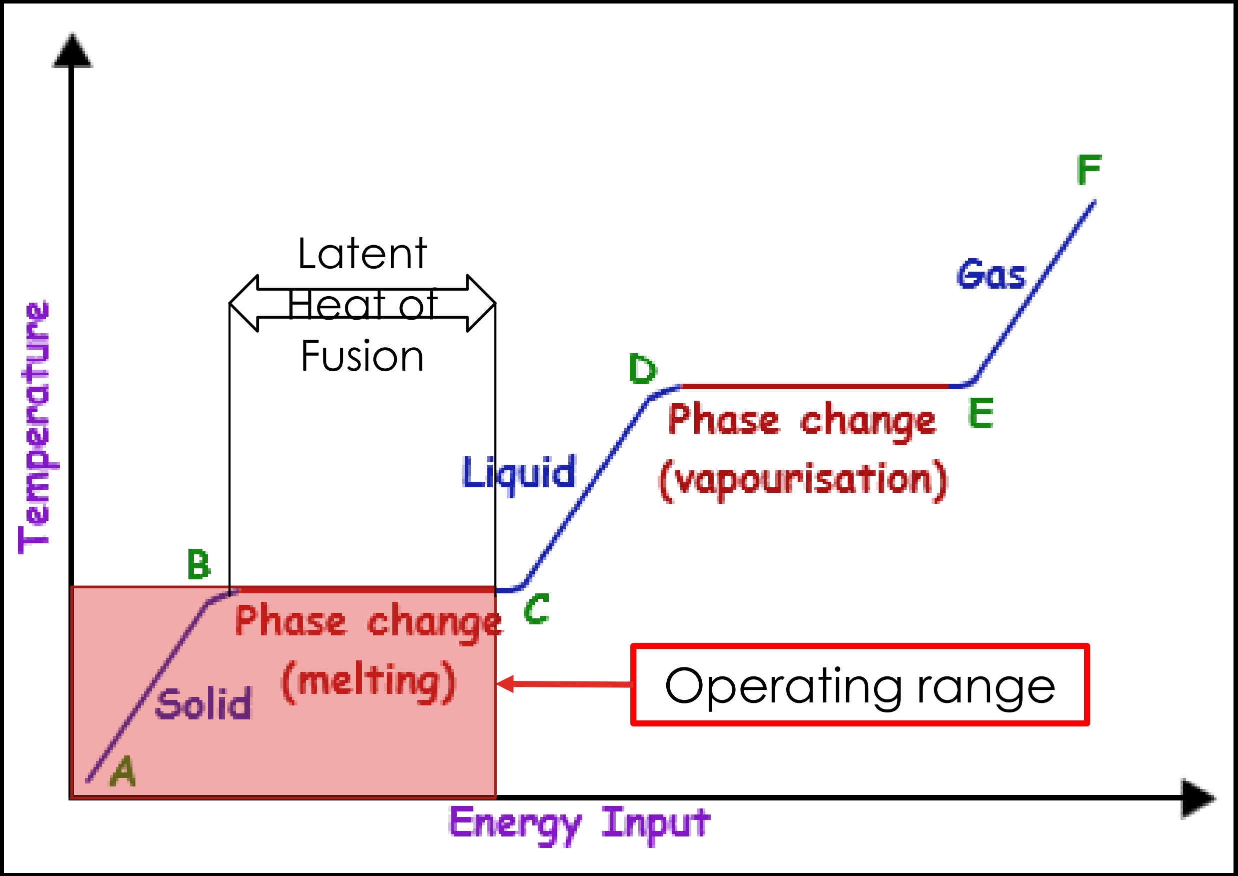
- Background
- Final Design Concept
- Model Analysis
- Prototyping & Testing
- Budget
- Risk Management
- Summary

MOTIVATION



- New solutions for electronics cooling
- Power Semiconductors
  - Found in jet engine's ignition units and power regulators
  - Thermal management is critical
- Customer's need
  - A highly-reliable, low- weight heat dissipation solution for power semiconductors in jet engine systems

BACKGROUND



Temperature
Energy Input
Latent
Heat of
Fusion
A
B
C
D
E
F
Solid
Phase change
(melting)
Liquid
Phase change
(vapourisation)
Gas
Operating range

PROJECT GOALS

- Create a heatsink containing a Phase Change Material (PCM)
  - Store thermal energy and reject it through natural convection
  - Serve as thermal bridge between power semiconductor base and housing wall
- PCM
  - Melting temperature within operating range (115-125°C)
  - Able to act as thermal capacitor
- Integration

Objectives

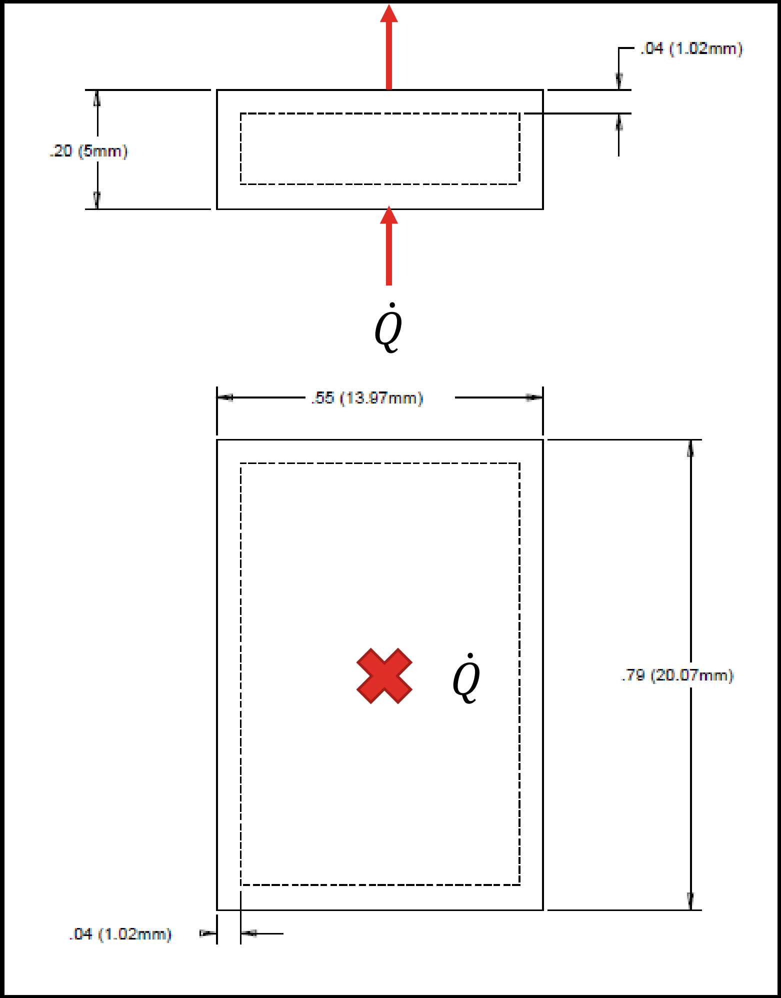
- Identify ideal PCM for heatsink
  - Given operating temperature range 115-125°C
- Numerical model to test heatsink performance
- An experimental rig for validation of the model
- Design parameters

Constraints

- Time
- Allocated budget
- Integration

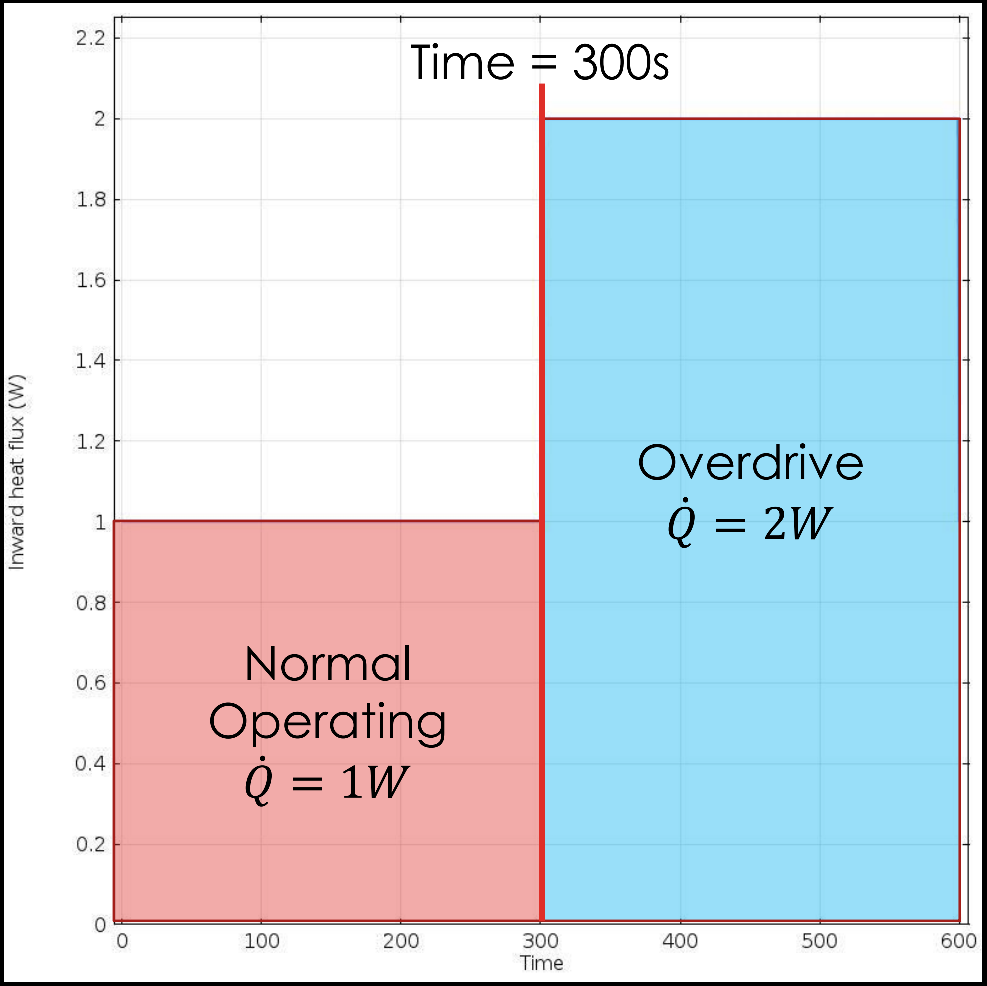
FINAL DESIGN CONCEPT

Component	Material
Base	molybdenum
Heat Sink	aluminum
PCM (inside heat sink)	solder
Housing (each wall)	aluminum



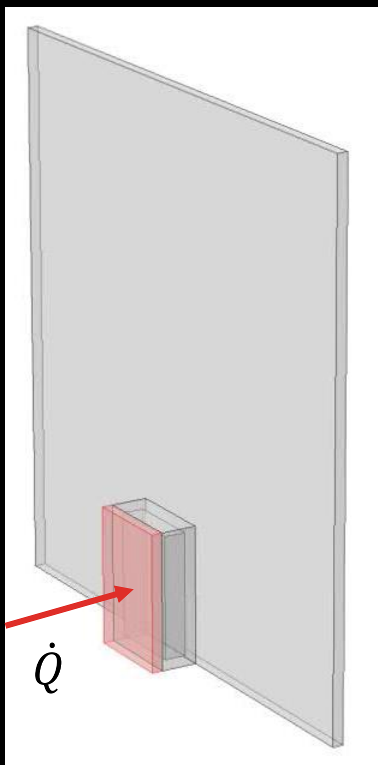
PHYSICAL MODEL

- Example operating period
- Normal Operation
  - 1W heat generation
- Overdrive
  - 2W heat generation
  - 5 minutes

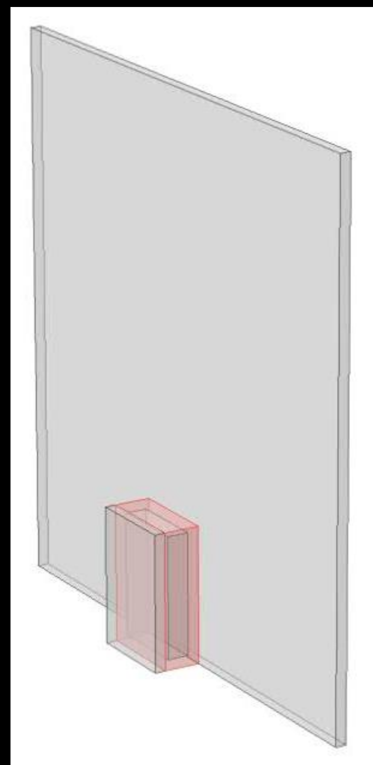


Kegan Dellinger

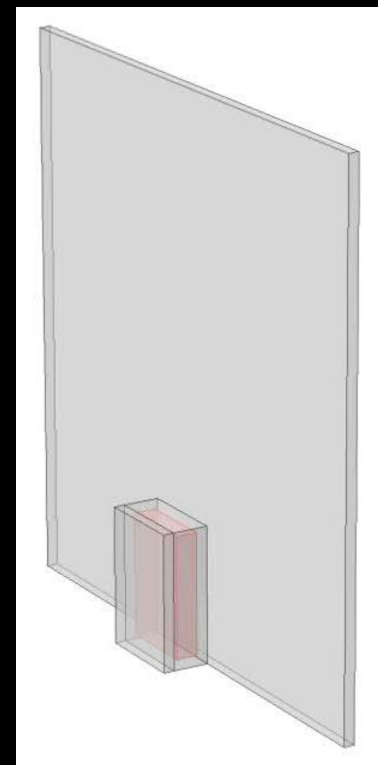
PREVIOUS MODEL



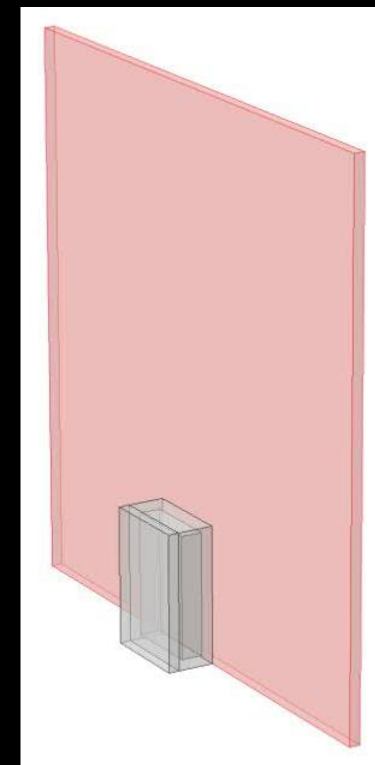
Molybdenum Base



Aluminum Heat Sink

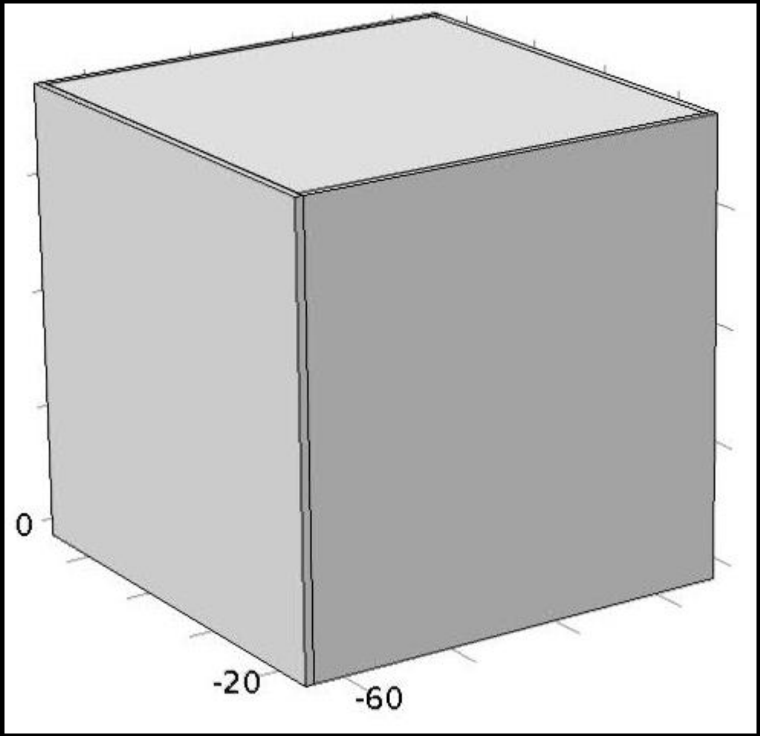


PCM

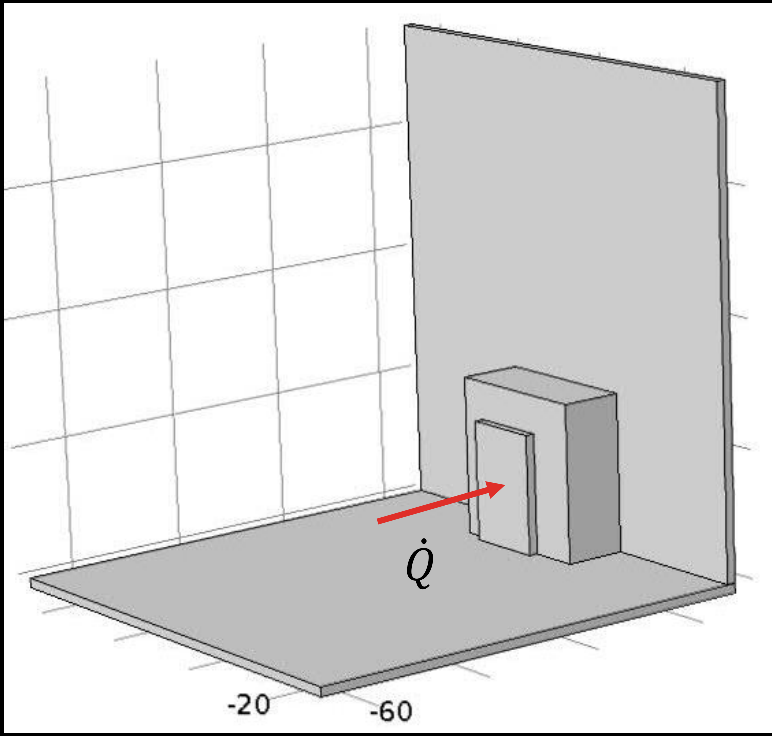


Aluminum Housing

REVISED MODEL

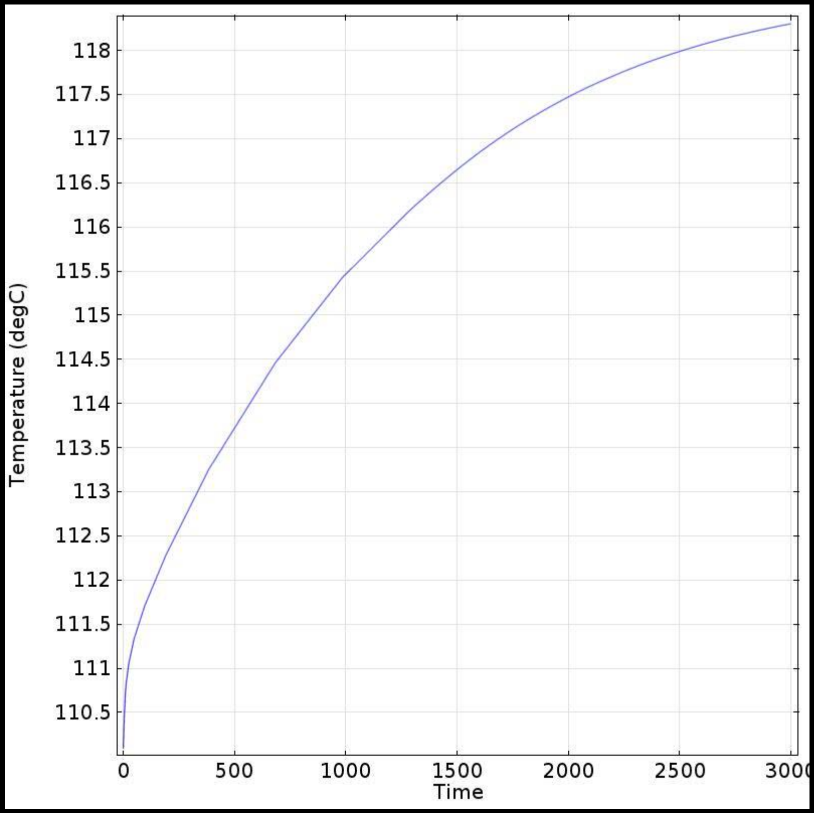


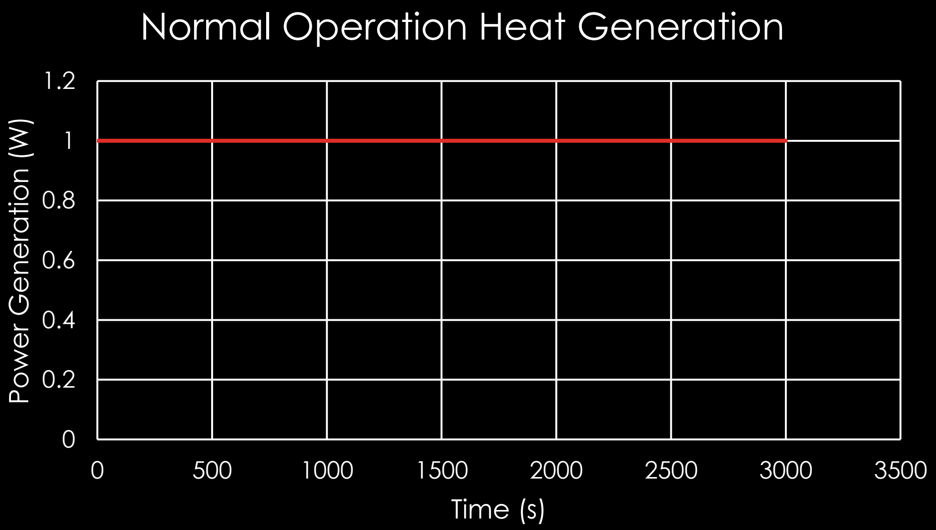
Assembly



Open View

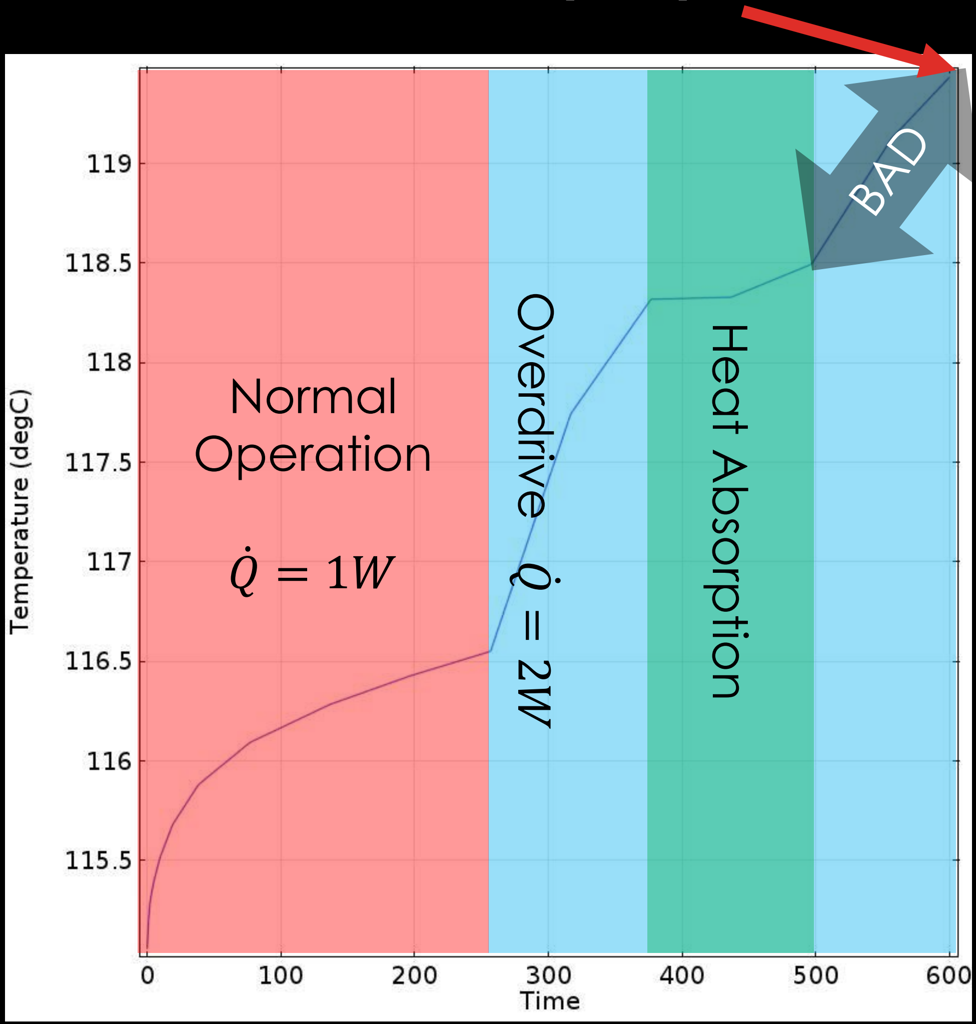
NORMAL OPERATION

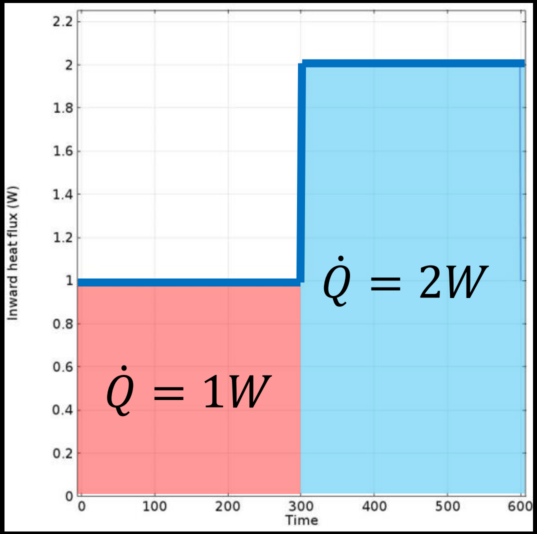


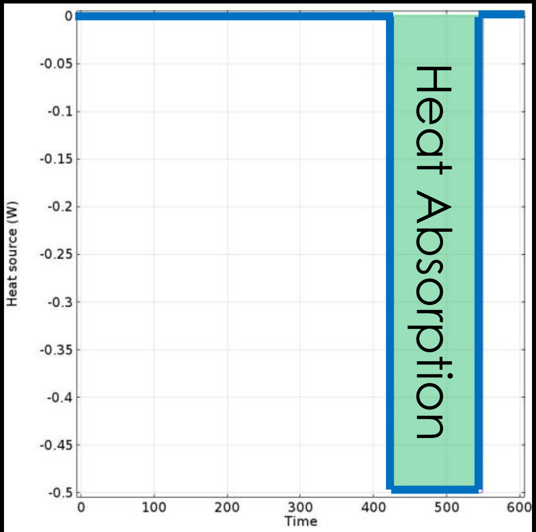


TRANSIENT RESULTS

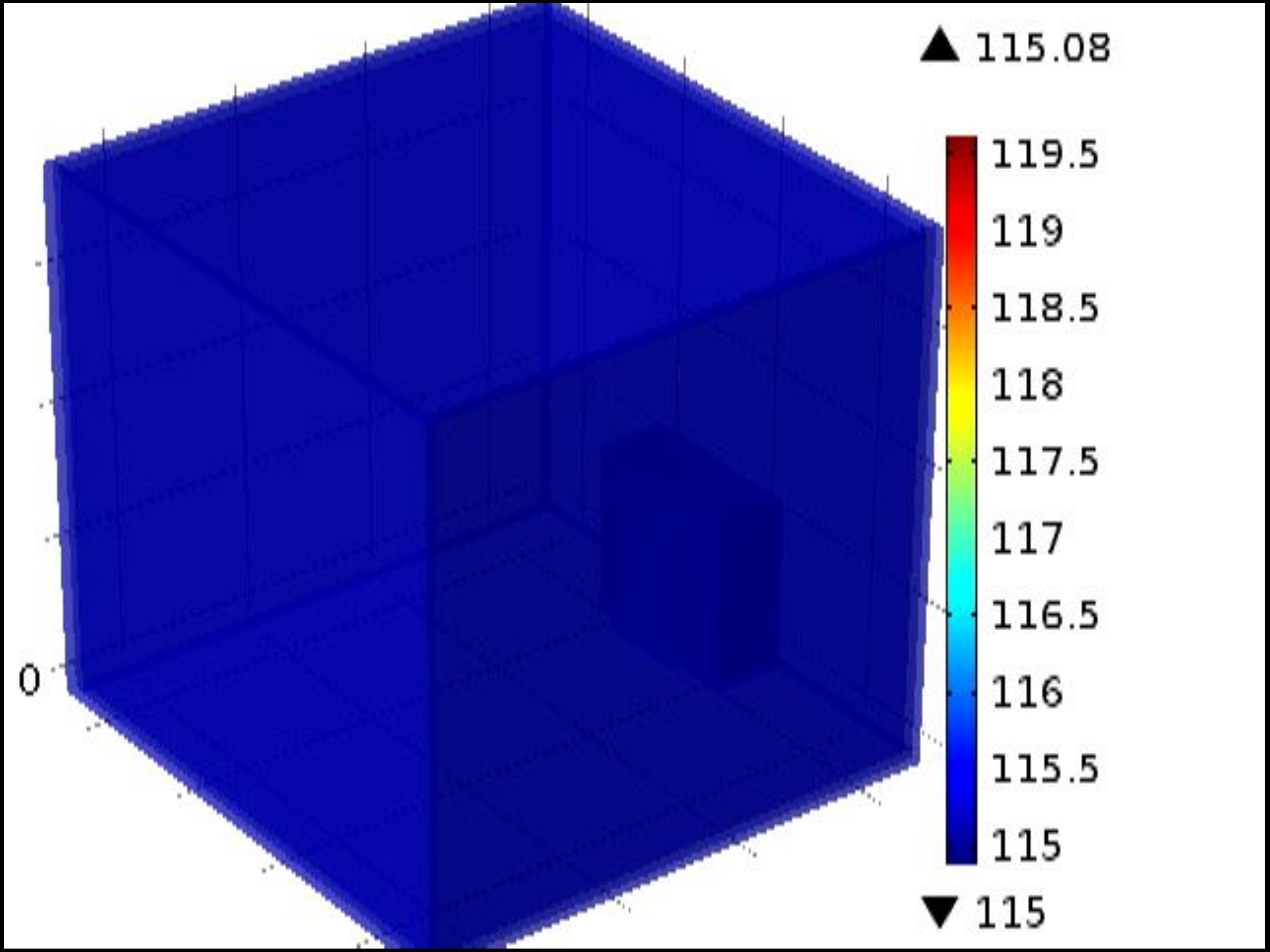
Does not exceed 125°C, T(600s) = 119.5°C







TRANSIENT MODEL

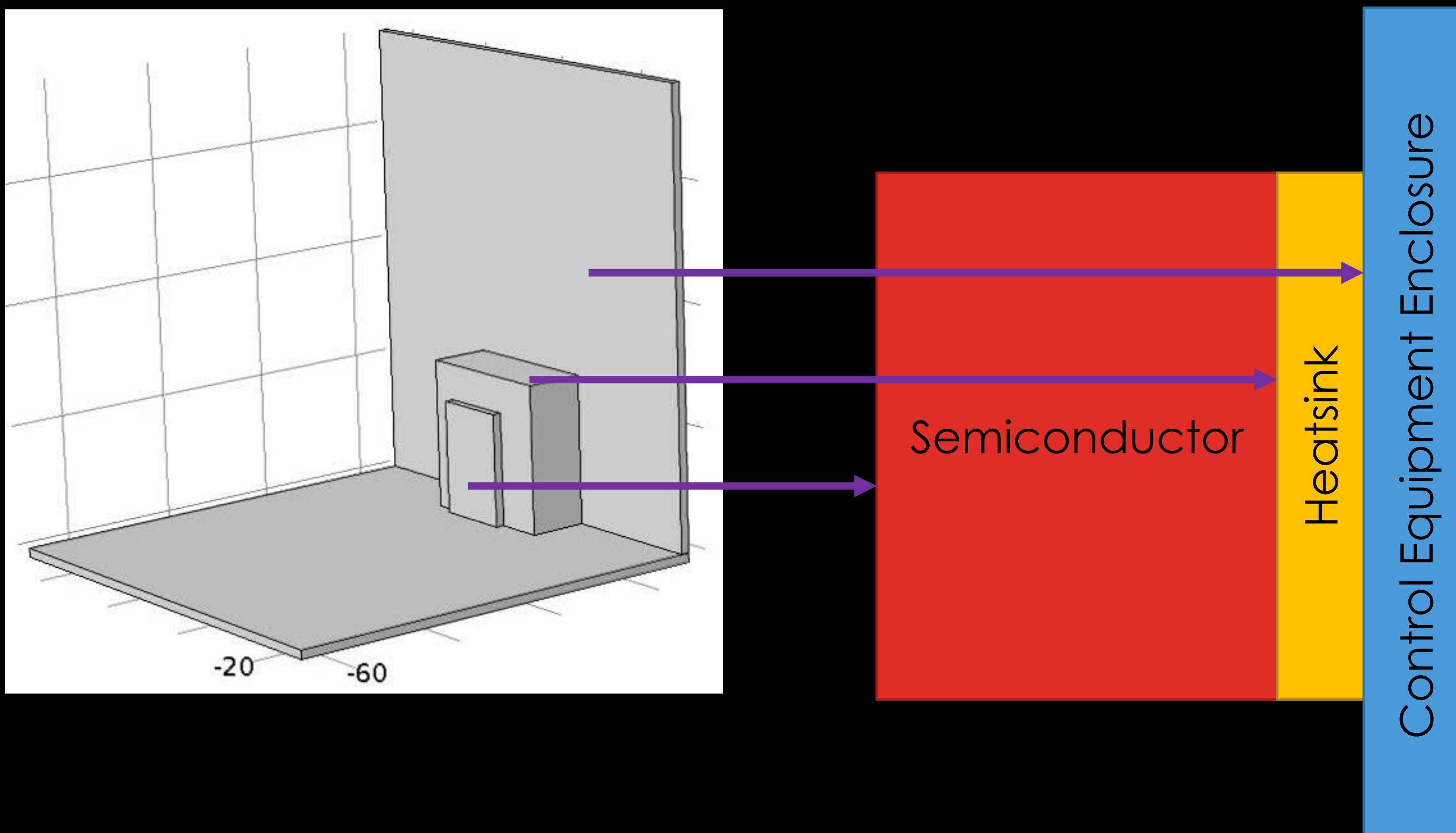


COMSOL RESULTS

- Current model works
  - Loses thermal "control"

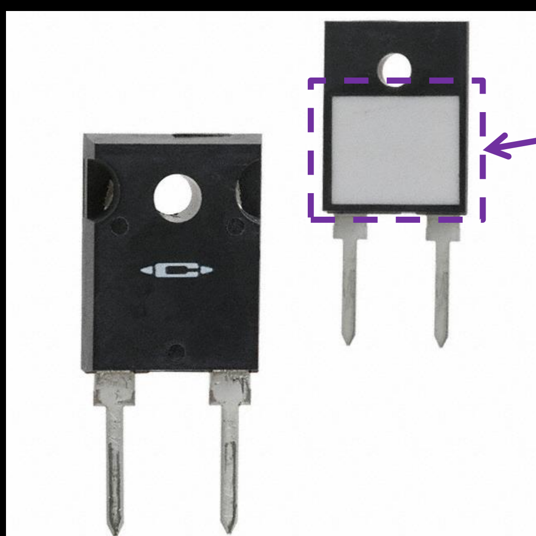
- Requires more PCM
  - Total amount is limited by other components
  - More PCM means degraded normal operation performance

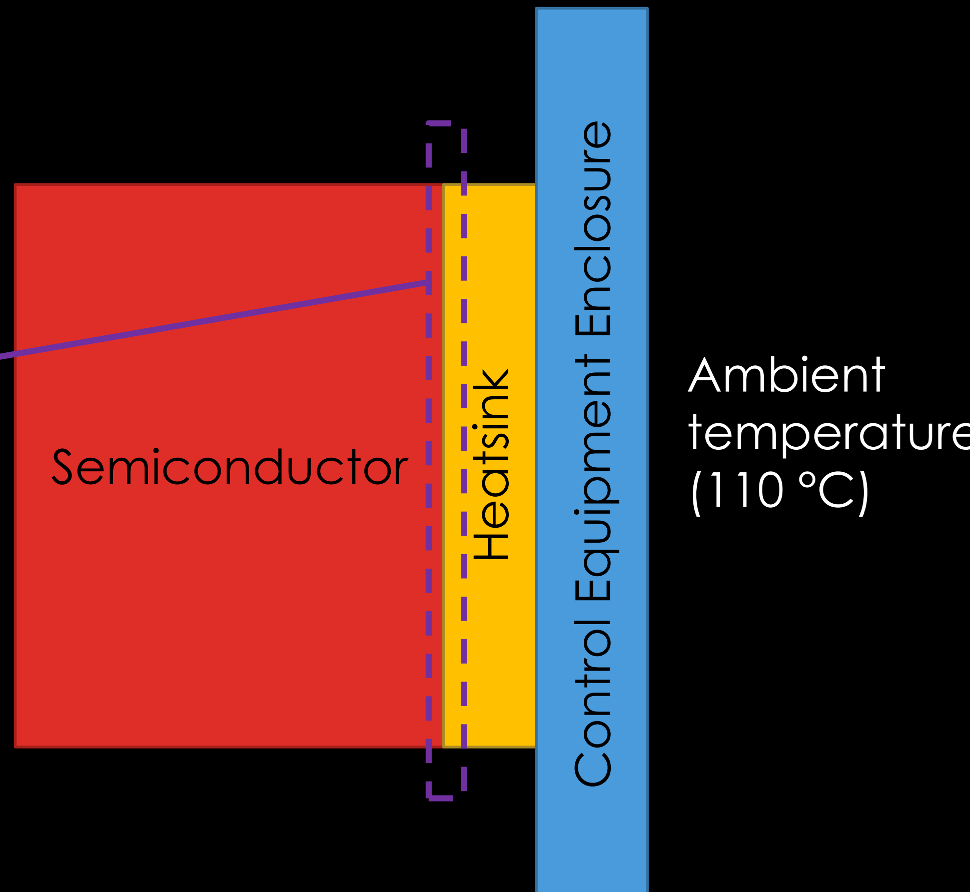
PROTOTYPING AND TESTING



PROTOTYPING AND TESTING

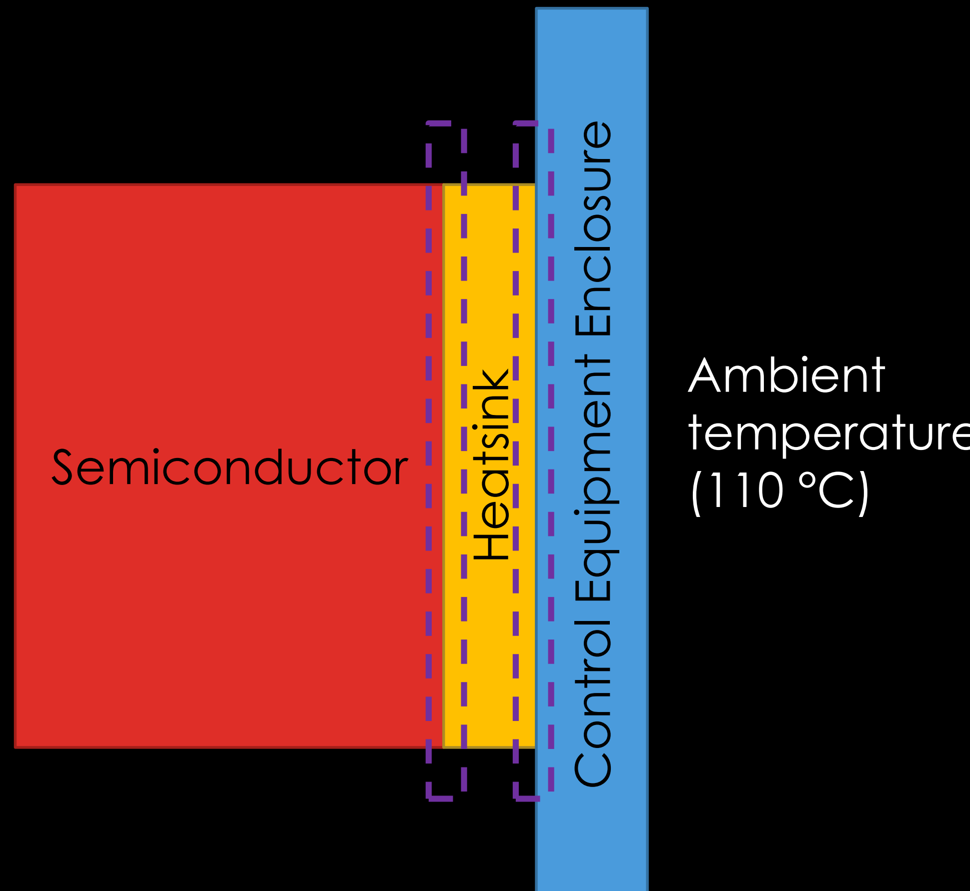
- MP9100 resistor **(Caddock)**: Will use Joule heating to simulate heat flux from semiconductor





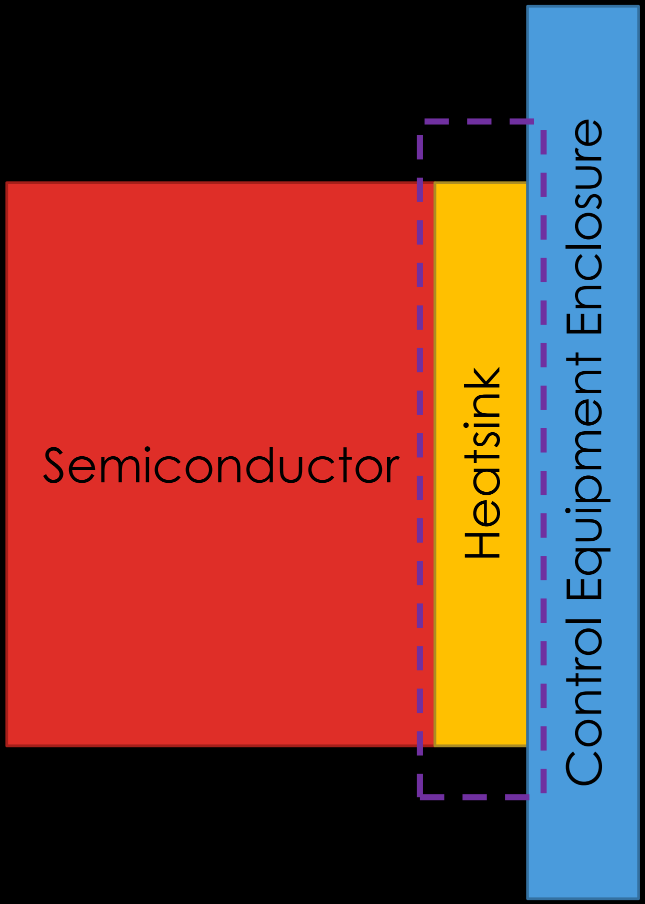
PROTOTYPING AND TESTING

- Hi-Flow 300P **(Berquist)**: Will melt and flow into contact surface imperfections to reduce contact resistance
  - Continuous operating temperature: 150°C
  - Thermal conductivity: $1.6\ \frac{W}{m \cdot K}$



PROTOTYPING AND TESTING

- Heatsink:
  - 52In-48Sn solder **(IndiumCorp)**:
    - Working to obtain free sample size
  - Copper/aluminum tape **(3M)**:
    - Thickness similar to desired wall thickness
    - Easy to shape
    - Easy to assemble
    - Working with sponsor to develop ultimate manufacturing plan
- Aluminum plate:
  - **Unison** will provide plates of specified thickness



Ambient temperature (110 °C)

PROTOTYPING AND TESTING

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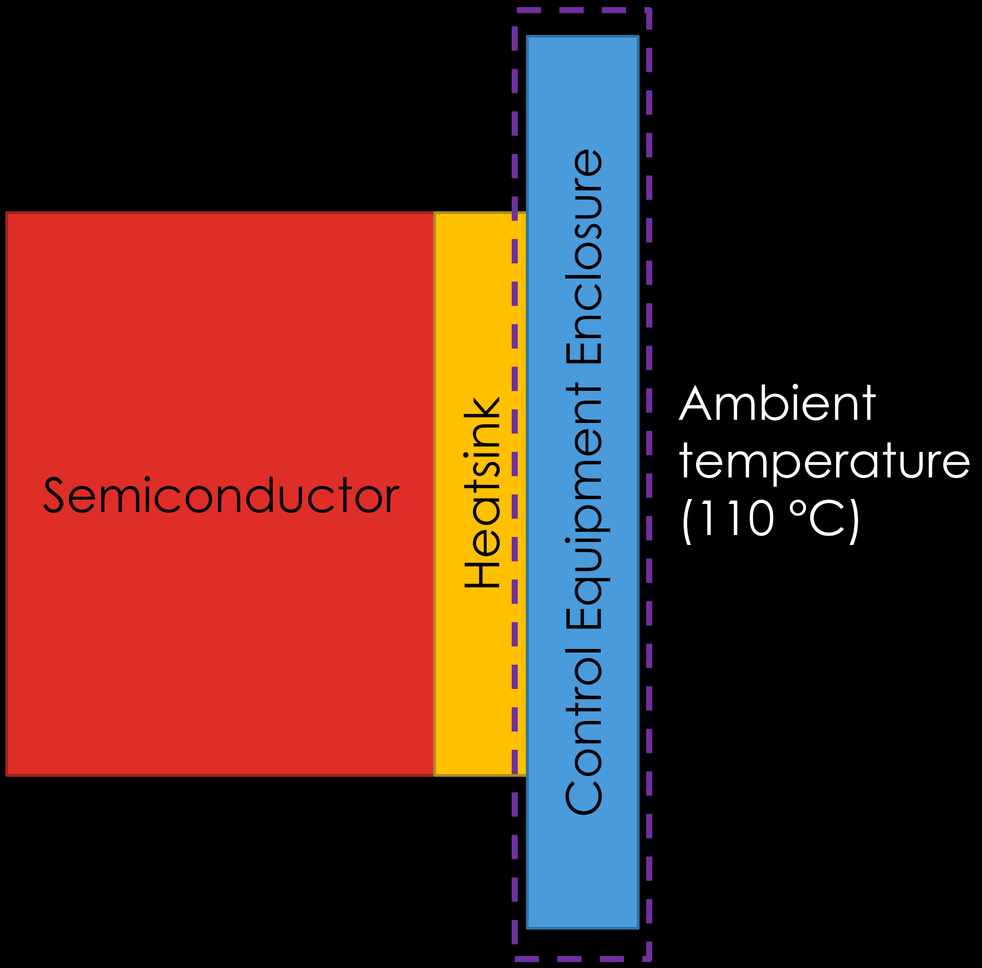
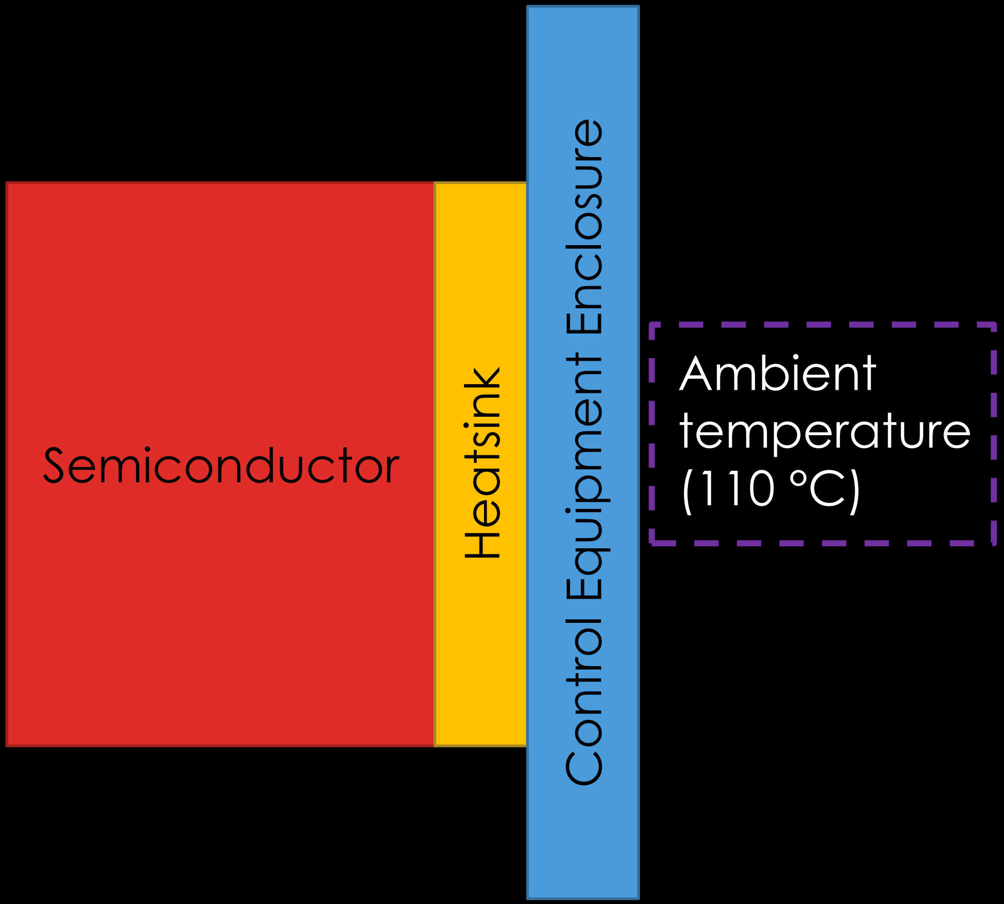


Daniel Canuto

PROTOTYPING AND TESTING

- Test setup will be enclosed in a laboratory oven
  - Type K thermocouples **(Omega)** will be used for temperature monitoring
    - Thermal contact tape **(3M)** for mounting
- NI 9211, cDAQ 9174, and LabView **(National Instruments)** will be used for data logging/recording
  - Four thermocouple inputs



BUDGET

Material/Equipment	Vendor	Amount	Unit Cost (USD)	Total Cost (USD)
MP9100 resistor	Digi-Key	1 pc.	10.90	10.90
Thermal contact tape	eBay	1 spool	4.50	4.50
Aluminum tape	eBay	1 spool	40.00	40.00
Hi-Flow 300P*	Orion	1 pc.	48.00	48.00
NI 9211*	National Instruments	1 pc.	351.00	**351.00**
cDAQ 9174*	National Instruments	1 pc.	762.00	**762.00**
LabView Full	National Instruments	1 license	2699.00	**2699.00**
DC power supply*	Digi-Key	1 pc.	489.00	**489.00**
Lab oven*	Mellen	1 pc.	2499.99	**2499.99**
Type K thermocouple*	Omega	4 pcs.	30.00	120.00
Aluminum bar*	Various	26 cu. in.	5.00	5.00
52In-48Sn solder*	IndiumCorp	1 spool	49.95	49.95
Machining*	N/A	2 hours	20.00	40.00
Remaining Budget (including starred items):				**-5119.34**
Remaining Budget (excluding starred items):				**1944.60**

Starred items obtained at no cost

- Allocated budget was $2,000
  - Majority of cost would be incurred in purchasing testing equipment: One-time capital investments
  - Well under-budget (excluding starred items) and do not anticipate any other major purchases

RISK MANAGEMENT

- Partial FMEA Analysis:
  - Failure modes: Insufficient heat absorption during normal/overdrive phases
    - Causes:
      - Insufficient sealing/volume of PCM
      - Insufficient break-in of thermal interface material
      - Insufficient pressure placed on contact surfaces
  - Analysis indicates that careful monitoring of fabrication processes is critical to heatsink (and hence semiconductor) reliability
- Safety/environmental issues:
  - Solder toxicity: Need to ensure proper handling/disposal
  - Minor burn risks: Need to wear PPE (thermally insulative gloves) when handling test setup after experiments
  - Minor shock risks: Need to exercise care when handling DC power supply terminals

SUMMARY

- Objective is to create a low-weight, high-reliability thermal management solution for high ambient temperatures
- Accomplishments:
  - Three-dimensional heat transfer model
  - Experimental design
  - Well under-budget
- Future work:
  - Procure/assemble/run test setup
  - Develop final manufacturing plan

QUESTIONS?