PHASE CHANGE MATERIAL TRANSIENT HEATSINK FOR POWER SEMICONDUCTOR

Midterm Presentation 1

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OUTLINE

- Background
  - Motivation
  - Goal/scope
  - Objectives/constraints
- Design Progress
  - System schematic
  - Steady-state analysis
  - Material selection
- Future Plans
- Summary

MOTIVATION

- Power semiconductors
  - Found in jet engine's ignition units and power regulators
- Operating limits & thermal management
  - Crucial part of design process
- Customer's need
  - A highly-reliable, low-weight heat dissipation solution for power semiconductors

GOAL/SCOPE

- Create a heatsink containing a Phase Change Material (PCM)
  - Bridge between the power semiconductor and the housing
    - Temporarily store thermal energy if needed, then reject it through natural convection
- PCM
  - Melting temperature within operating range
  - Able to act as thermal capacitor

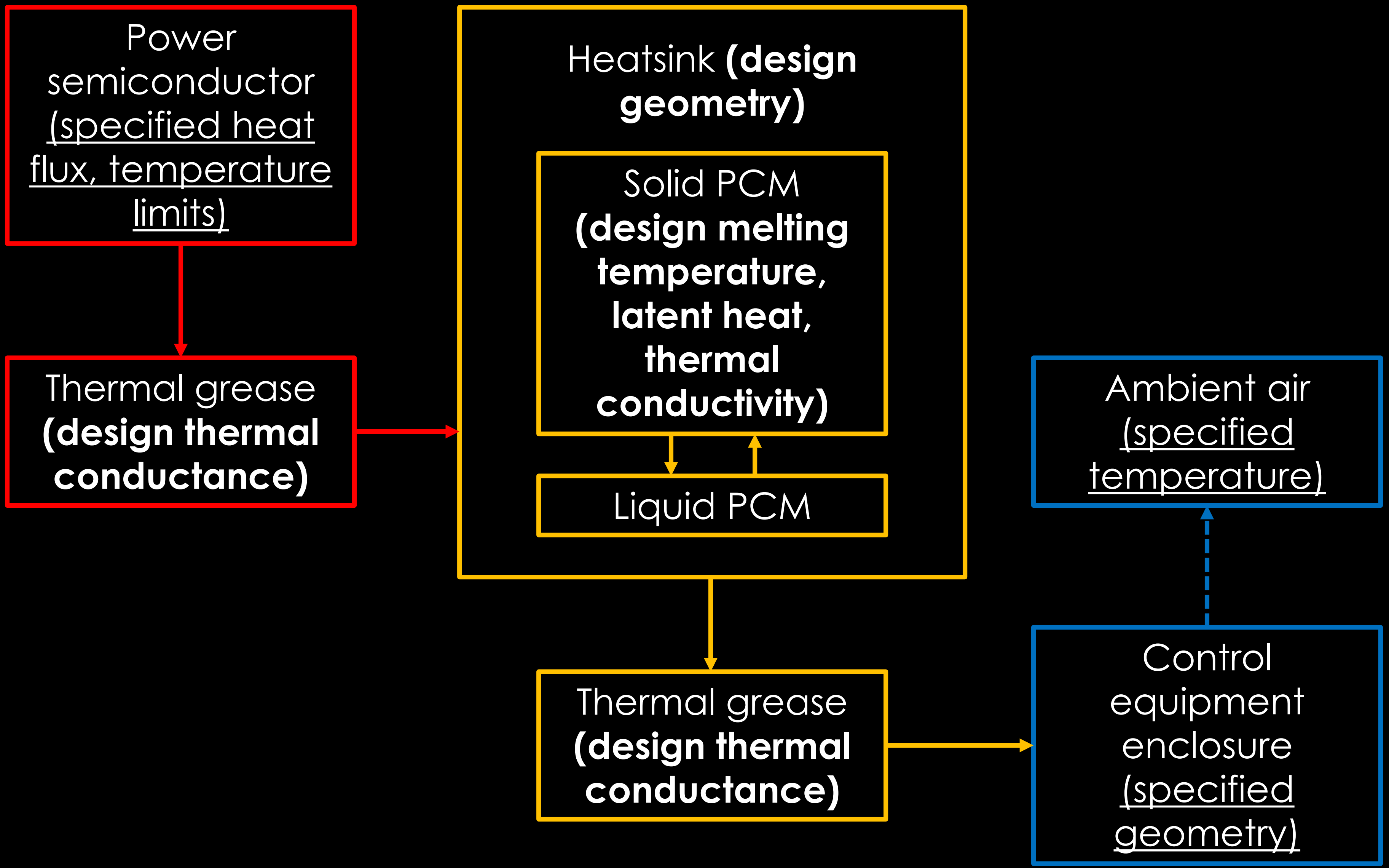
Objectives

- 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

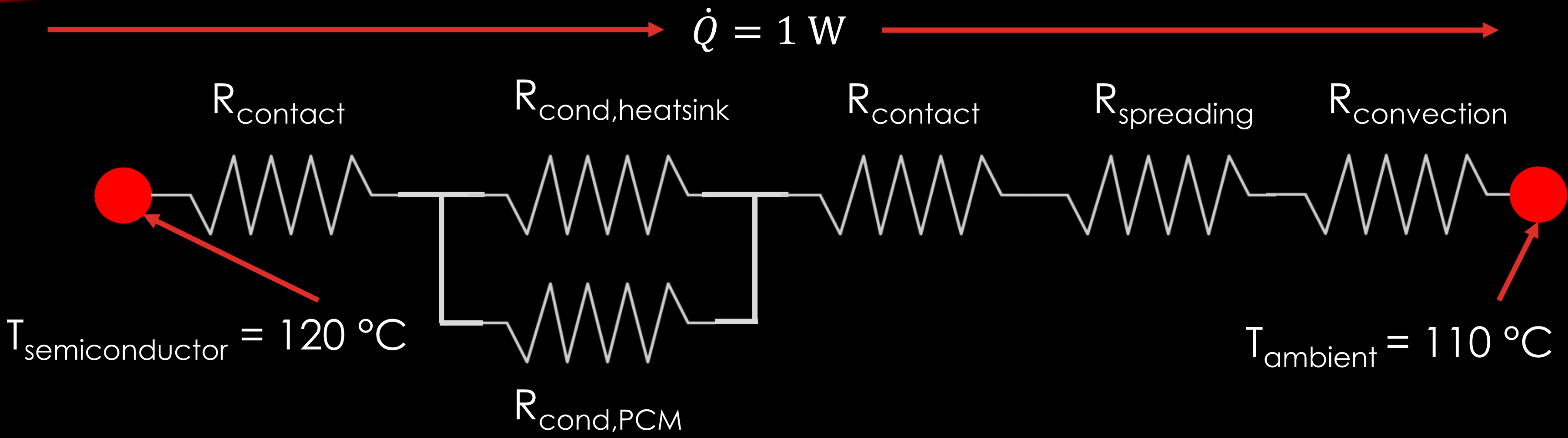
Constraints

- Time
- Allocated budget
- Integration

HEAT TRANSFER SCHEMATIC

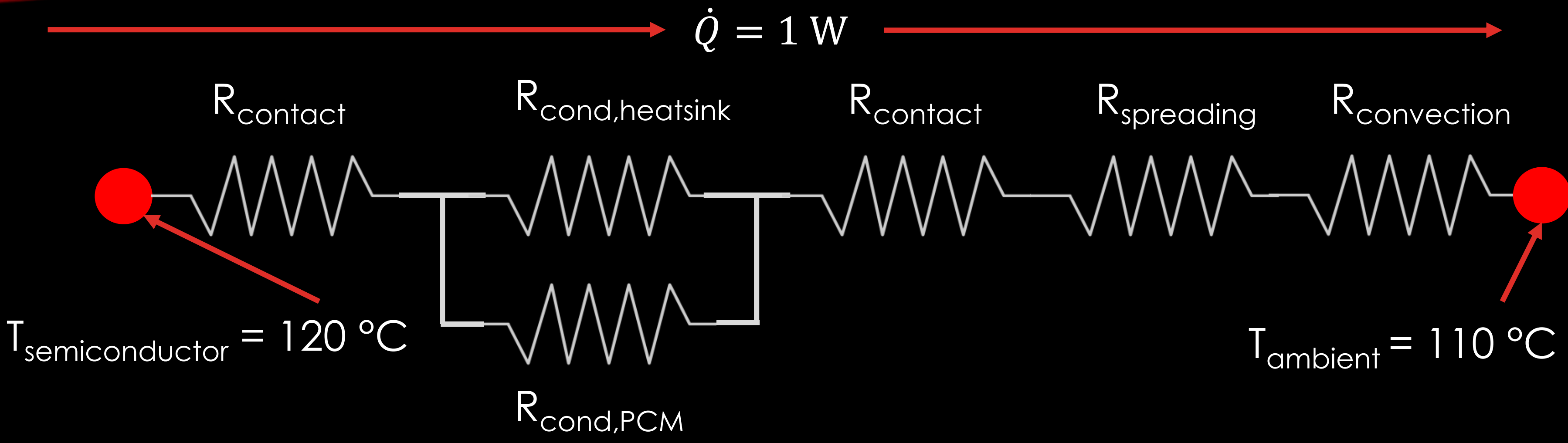


STEADY-STATE ANALYSIS



$$\dot{Q} = \frac{\Delta T}{R_T} \rightarrow R_{T,max} = \frac{10°C}{1W} = 10\,\frac{°C}{W}$$

STEADY-STATE ANALYSIS

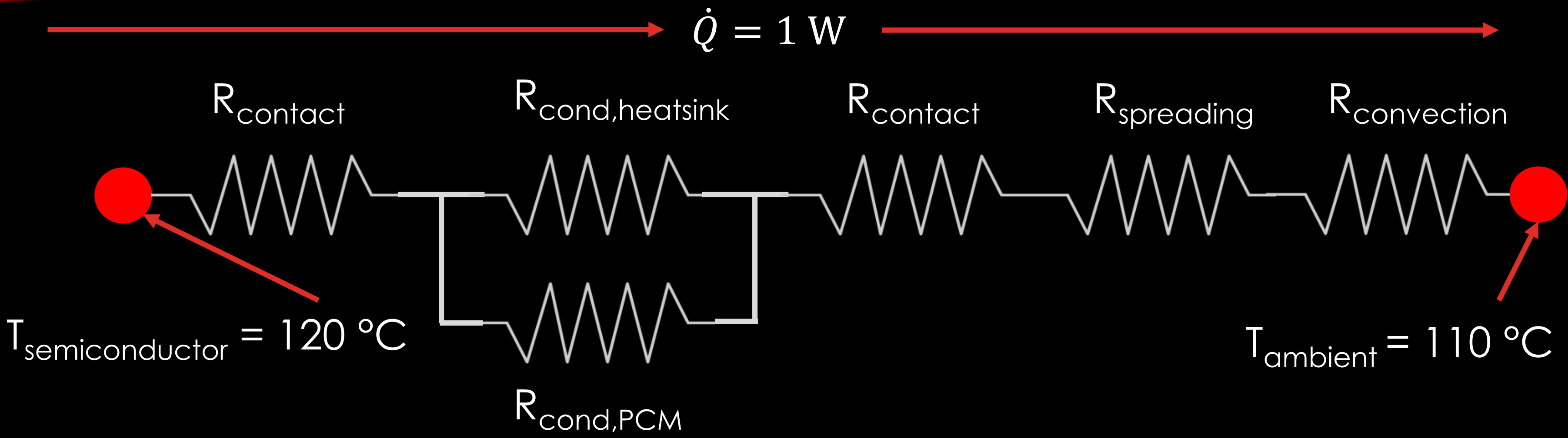


$$R_{convection} = \frac{1}{hwl}$$ → Maximize convection heat transfer coefficient

$$R_{contact} = \frac{1}{h_c A_c}$$ → Maximize contact conductance and contact area → **glycerin as thermal grease**

$$R_{cond} = \frac{L}{k A_s}$$ → Maximize thermal conductivity, consider trade-offs elsewhere → **aluminum as heatsink material**

STEADY-STATE ANALYSIS

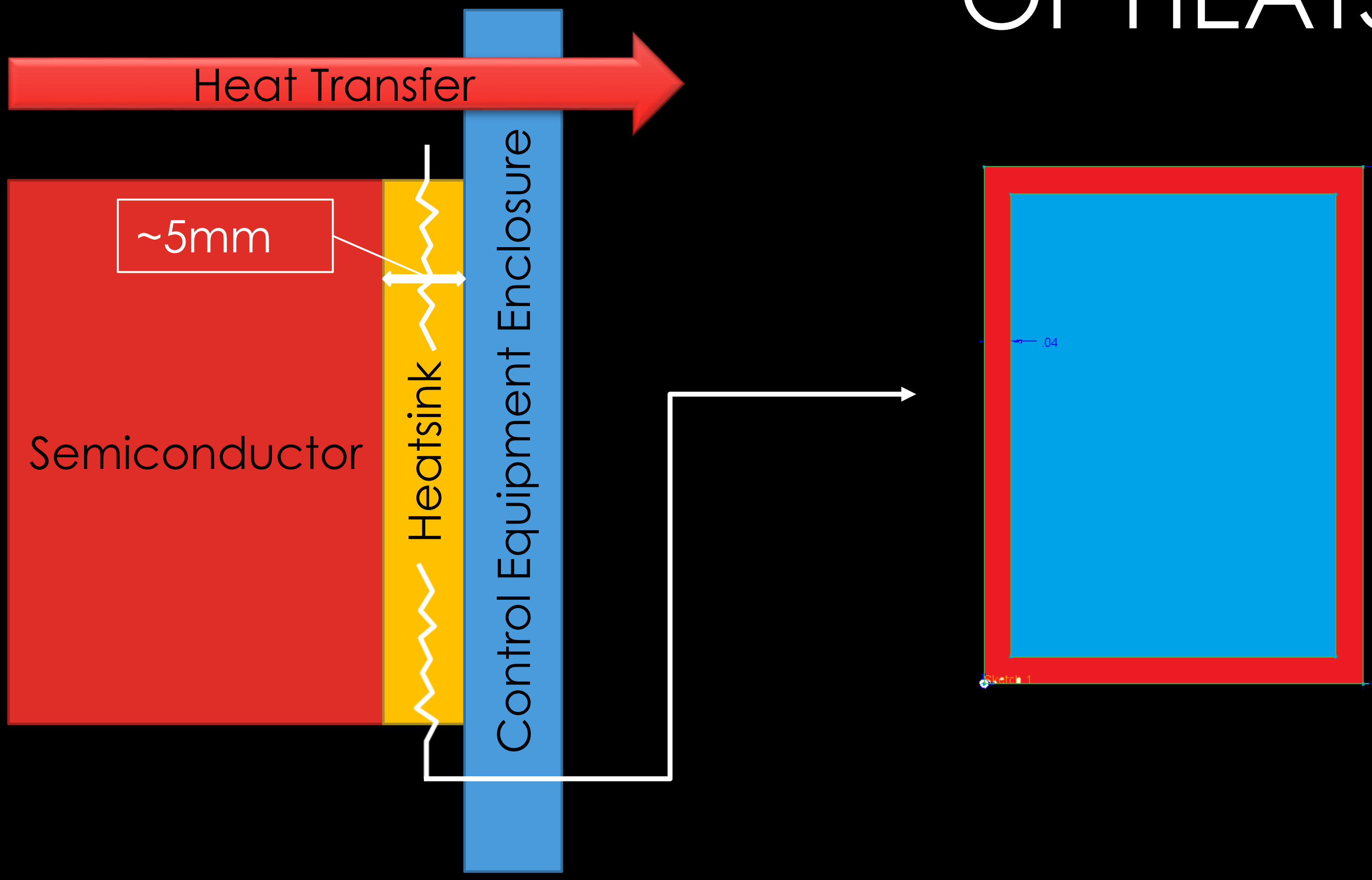


$$R_{convection} = \frac{1}{hwl}$$

$$R_{convection} = 10.6\,\frac{℃}{W} > R_{T,max}$$

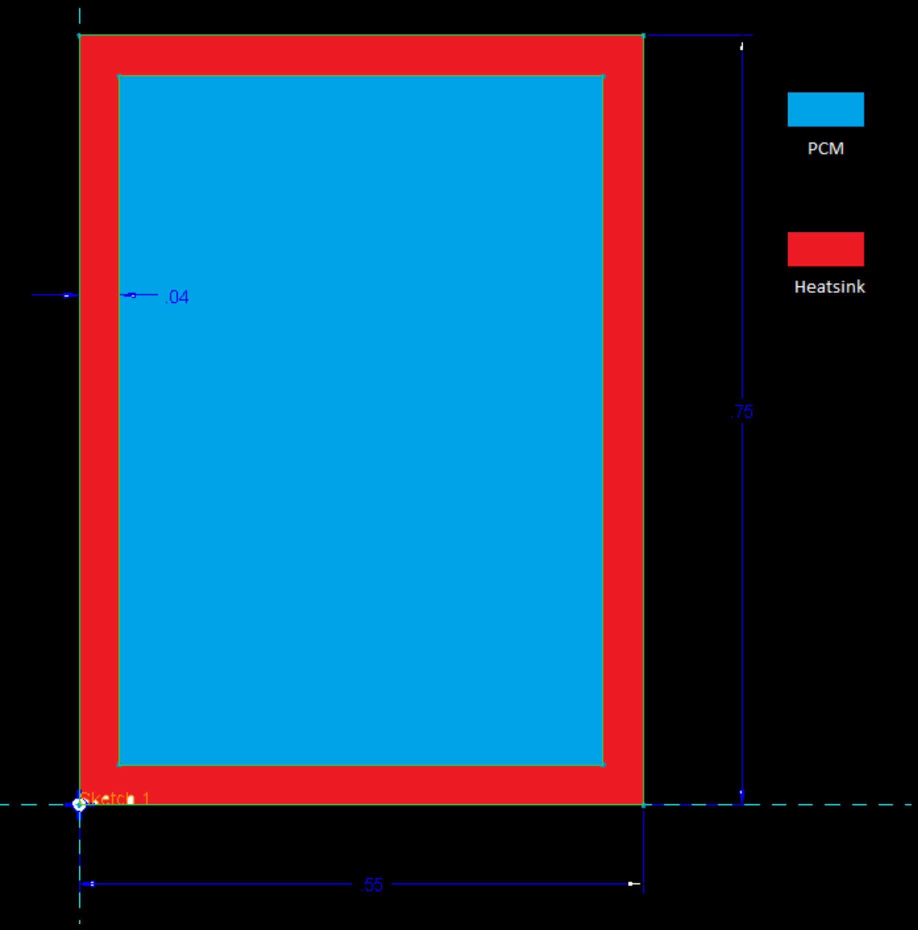
Need to improve convection heat transfer coefficient

CROSS SECTIONAL AREA OF HEATSINK



CROSS SECTIONAL AREA OF HEATSINK

Design Concept 1



Pros
- Most amount of PCM
- Most basic structure

Cons
- Greatest pressure
- Greatest thermal resistance
- Machinability

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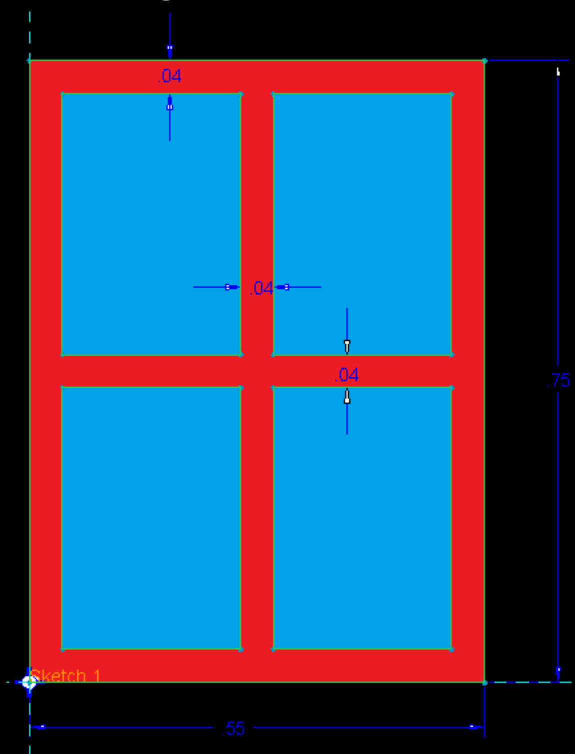
CROSS SECTIONAL AREA OF HEATSINK

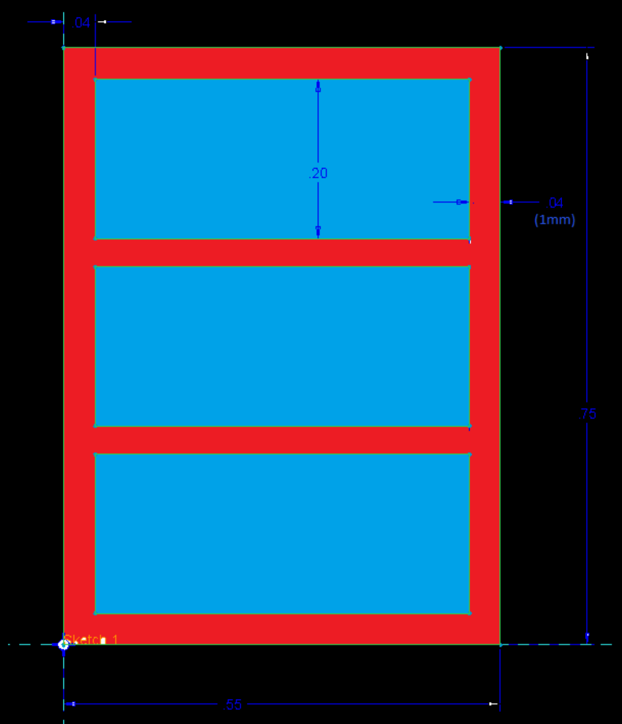
Design Concept 2.1



Pros
- Less thermal resistance
- Rigid structure

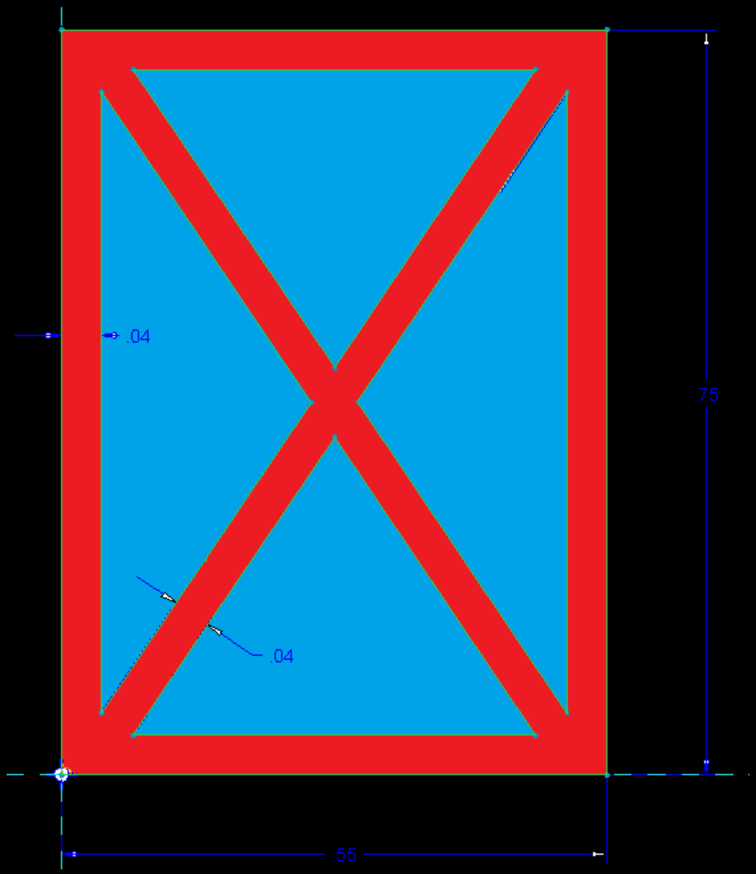
Cons
- Less amount of PCM
- Machinability

Design Concept 2.2



CROSS SECTIONAL AREA OF HEATSINK

Design Concept 3



Pros
- Less thermal resistance
- Rigid structure
- Expected to diffuse most heat

Cons
- Less amount of PCM
- Machinability

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PCM SELECTION

		Material						
		Solders					Other	
		52In-48Sn	Bi50-Pb28	In75-Cd25	Bi46.1-Pb34.2	Bi55.5-Pb44.5	Sulfur	Wax
Criteria	Melting Point (°C)	118	109	120	123	124	115	~60
	CTE (10^-6/K)	20	-	-	-	-	-	-
	Density (kg/m^3)	7300	-	-	-	10440	-	-
	Thermal Conductivity (W/m*K)	34	-	-	-	4	0.205	2
	Latent Heat of Fusion (kJ/kg)	28.47	-	-	-	-	-	-

FUTURE PLANS

- COMSOL model of heatsink designs
  - Thermal dynamics
  - Structural mechanics
  - Iteration
- Choose a heatsink design
  - Build prototype
- Design a testing apparatus
  - Build prototype

SUMMARY

- Patent search
- Steady-state model
- PCM selection
- Heatsink designs

QUESTIONS?