EML 4551

Unison Industries Forced Air-Cooled Heat Sink

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Team 19

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Project Recap

Lucas Pye

Project Review

- Unison Industries has tasked team 19 with developing a forced air, lightweight heat sink that must be able to dissipate 300W of heat and maintain a temperature of 135C max (preferably lower).

- Givens:
  - Board is 8.5”x7.25”
  - Ambient temperature is 85C (design for 105C)
  - MAX operating temperature is 135C
  - 24 Semiconductors heat sources to be arranged in sets divisible by 3

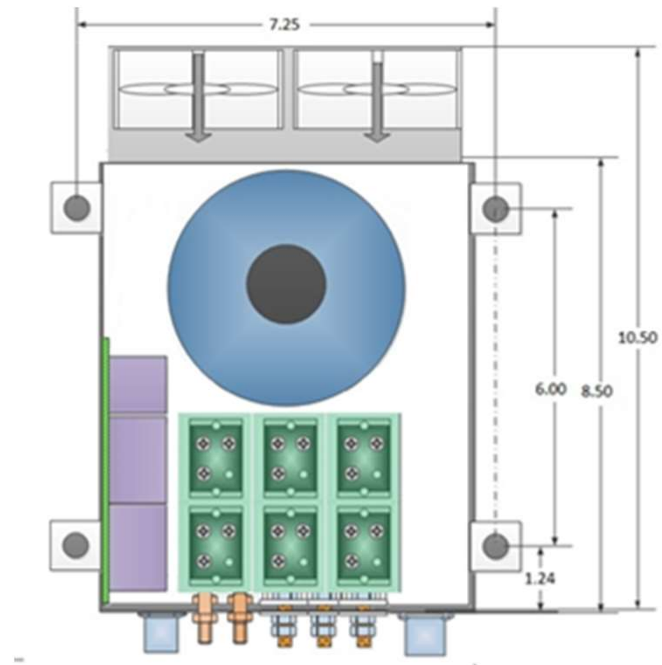

Figure 1: General Arrangement [2]

Lucas Pye

Recap

- Goals:
  - Dissipate Heat
  - Lightweight
  - Small Scale
  - Cost/Time Effective
- Assumptions:
  - Major components (i.e. fan) to be ordered.
  - Fan mounting is out of scope.
- Designing new components is costly, takes time, and difficult to maintain.
- We will observe the scalability of our generated concepts.
  - An additional bonus objective is to dissipate 800W of heat from a similar heat source.

Lucas Pye

Relations

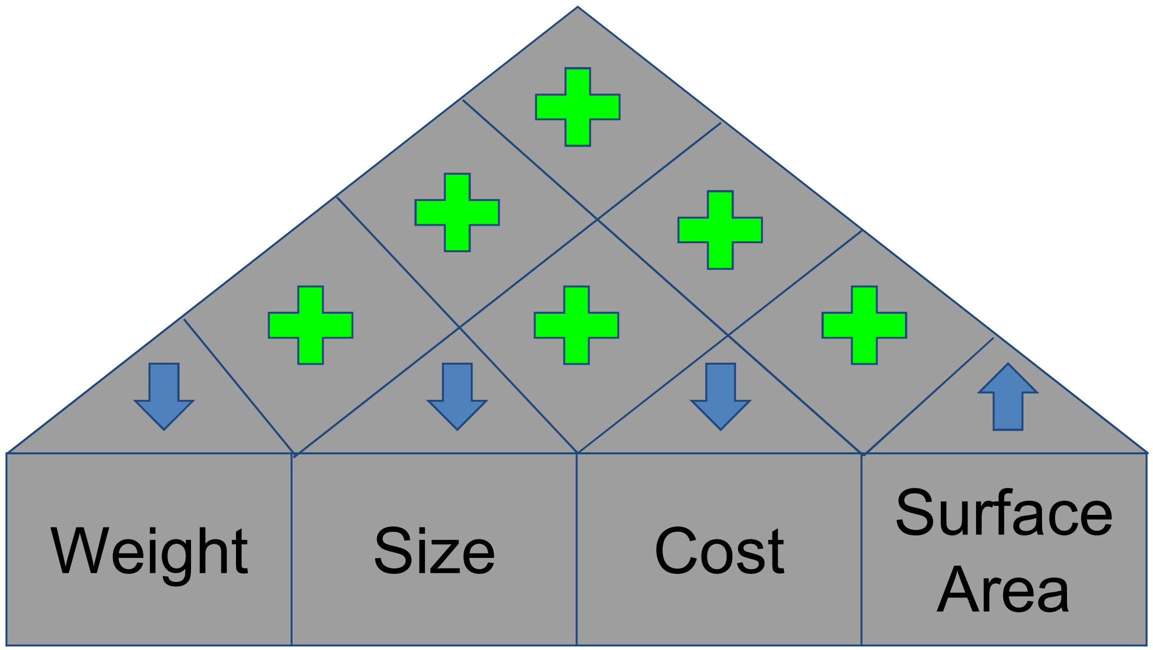

Figure 2: Relationship map

- Weight, size, and cost all decrease with one another, which is desired.
- Surface area, where it is desirable to have a maximum, will cause other categories to increase.

Lucas Pye

Optimization

- Newton's Law of Cooling:
  - $Q = h*A*\Delta T$
    - Q = heat (W)
    - h = Convective heat transfer coefficient ($W*m^{-2}*K^{-1}$)
    - A = surface area (m^2)
    - ΔT = Temperature Difference (K)
- We can manipulate h by changing flow conditions and material or A by changing the geometry.
- An increase in either h or A will result in a greater amount of heat being removed (desirable).

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Target Summary

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R_theta

- R_theta is an FEA program developed by Mersen.
- We will use this as a benchmarking tool.
- All products were modeled with the same thermal paste, which is a polysynthetic silver thermal paste.

- Program Inputs:
  - Dimensions
  - Environment
  - Flow Conditions
  - Source Layout
- Program Outputs:
  - Weight
  - Head Loss
  - Heat Distribution
  - T_Max/Min

Parker Harding

Target Concepts

❖ The first round of iterations in R_Theta, the heatsinks and fans were made largest. This specs an upper design bound.

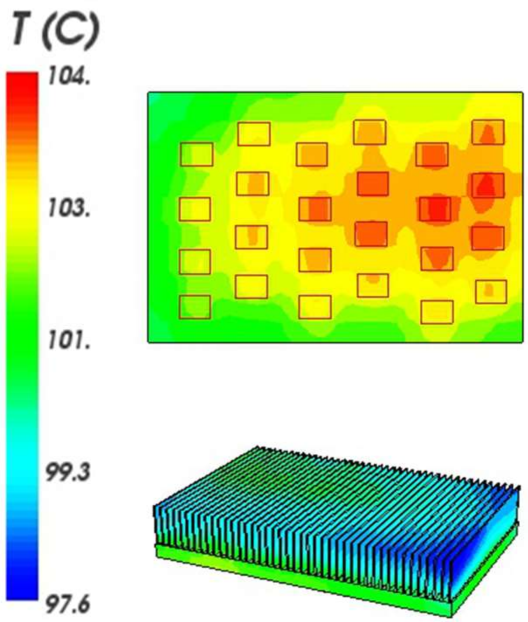

Figure 3: Concept 1 Heatmap

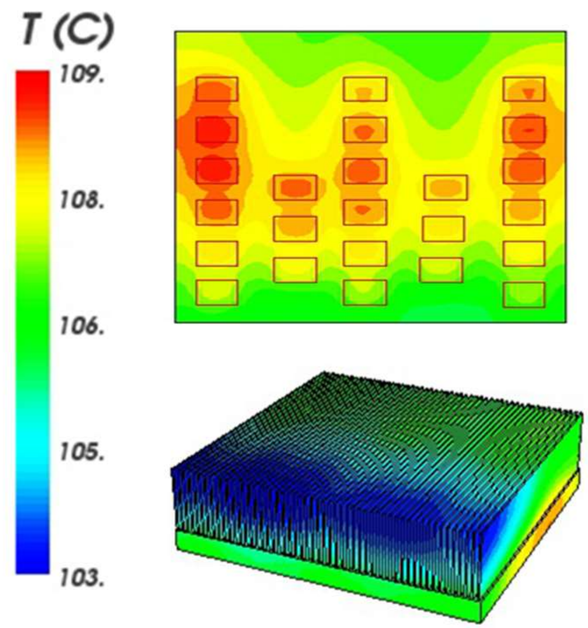

Figure 4: Concept 7 Heatmap

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Target Concepts

- The next targets were smaller in size, but lacked the heat dissipation of the previous, larger target concepts.

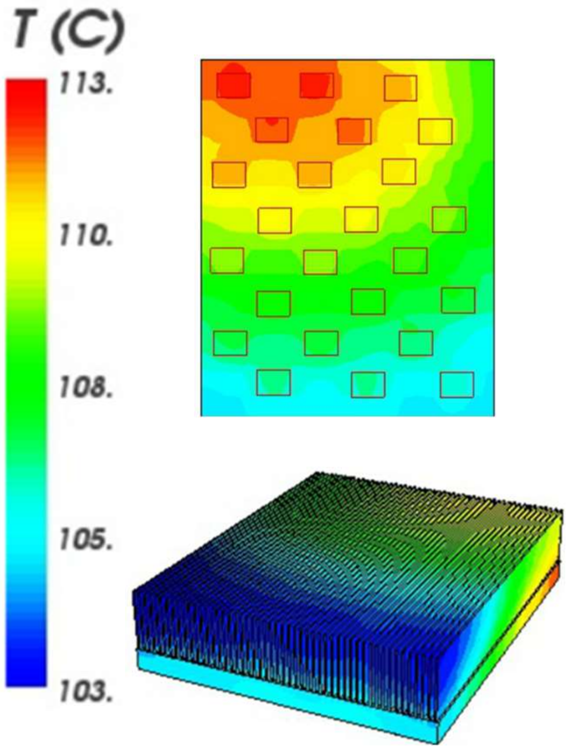

Figure 5: Concept 4 Heatmap

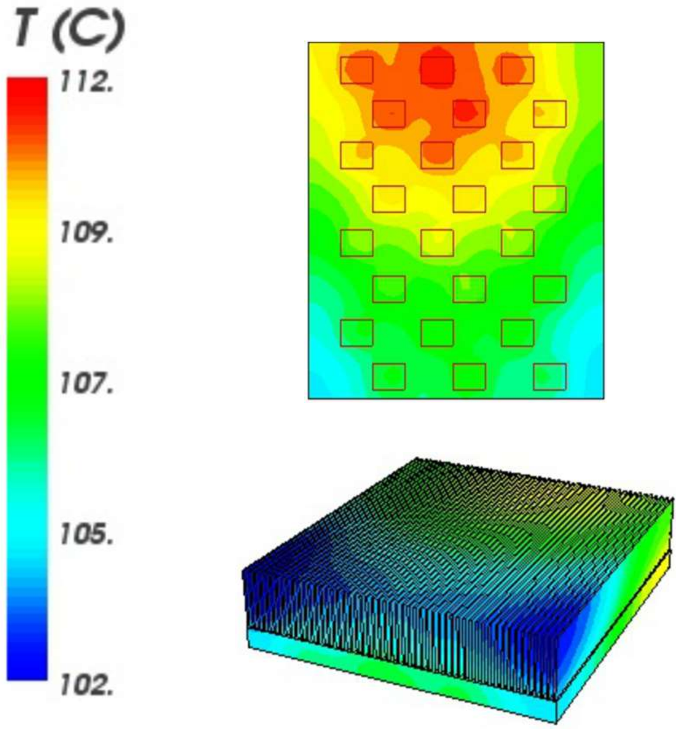

Figure 6: Concept 6 Heatmap

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R-theta Model

❖ The best model came in one of our final iterations in R-theta. This design provides a firm middle ground, and has the following specifications:

- Weight: 1.891 kg
- Head Loss: 21.840 Pa
- T max: 109C
- T min: 97C

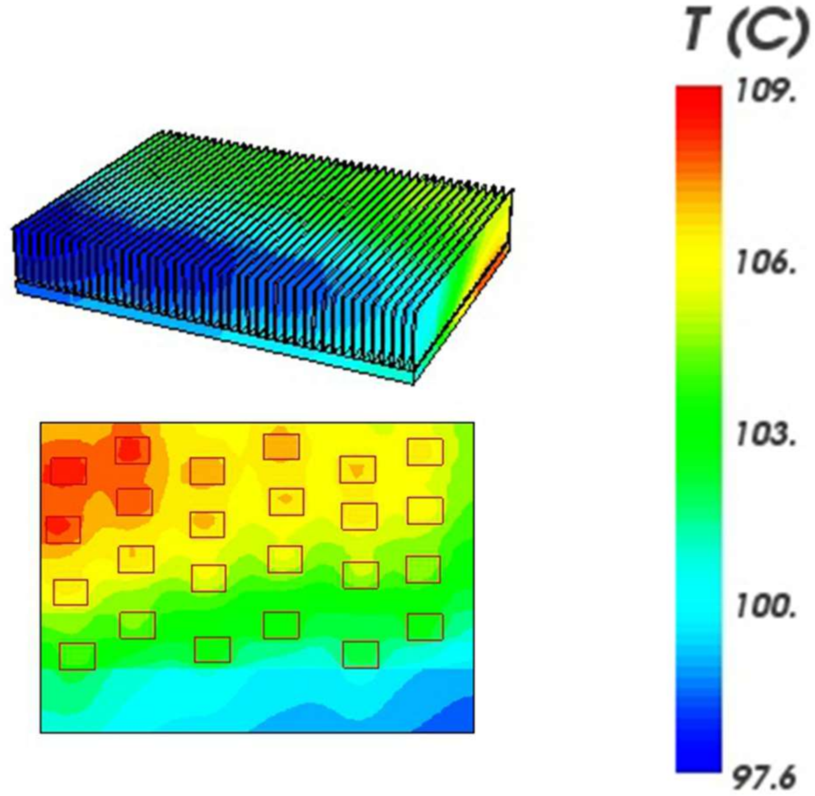

Figure 7: Concept 3 Heatmap

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Target Catalog

Metrics	Units	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6	Concept 7	Target
Material		Al	Al	Al	Al	Al	Al	Al	Al
Baseplate Width	mm	240.000	240.000	240.000	177.800	177.800	185.000	184.120	177.8
Baseplate Length	mm	160.000	160.000	160.000	215.900	215.900	178.000	203.200	215.9
Fin Height	mm	35.000	35.000	35.000	35.000	33.320	38.000	35.000	33
Fin Width	mm	1.270	1.270	1.270	1.280	1.280	1.270	1.270	1.27
Pressure Drop	Pa	45.203	45.203	21.840	27.402	27.402	35.800	38.451	28
Heatsink Weight	kg	2.128	2.128	1.891	2.165	1.434	2.360	2.550	1.4
Flow Rate	cfm	210.0	210.0	96.0	96.0	96.0	96.0	96.0	120
Max. Temperature	°C	104.0	104.0	109.0	113.0	128.0	109.0	112.0	110
Min.Temperature	°C	97.6	97.6	97.6	103.0	112.0	103.0	102.0	100

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Concept Generation

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Sandia Labs Heat Sink

- ❖ A heat sink that requires no actual fan would reduce the overall size of the system.
- ❖ Could use a DC motor to spin the actual heat sink such as the one Sandia Labs developed below:

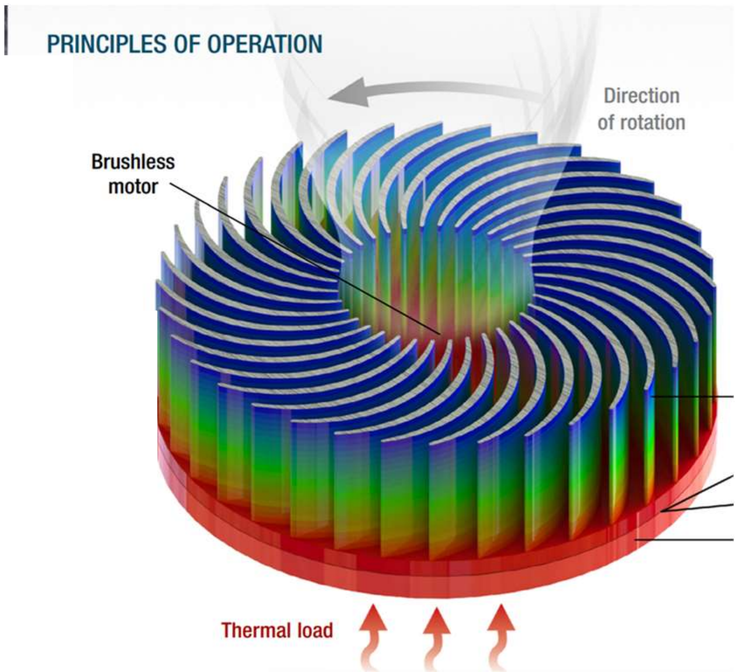

Figure 8: Spinning Heat Sink [1]

- ➢ 10x smaller than current CPU fans
- ➢ Extremely low thermal resistance
- ➢ Difficult to machine

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Foam Heat Sink

- ❖ Low profile heat sink with high amount of surface area
- ❖ Air flow would be low through foam
  - ➢ Jet flow used
- ❖ Pressure drop hard to measure
  - ➢ experiments need to performed to measure

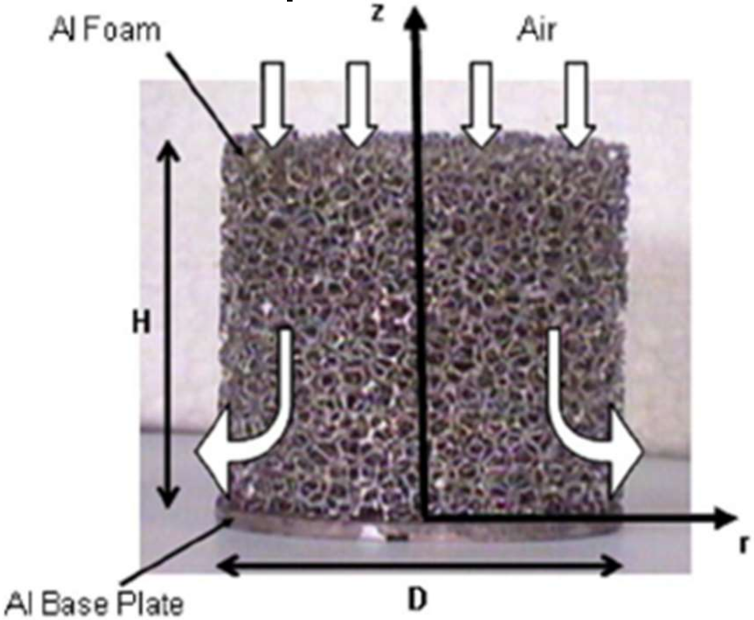

Figure 10: Foam heat sink [3]

- ❖ Low weight
- ❖ Difficult to construct

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Concept: Circular Fan Fin

Pros:

- ❖ Circular heat sink with wavy fins
- ❖ Fin shape creates larger surface area
- ❖ Fan easily mounted directly onto heat sink
- ❖ Fins contoured to follow fan rotation and airflow

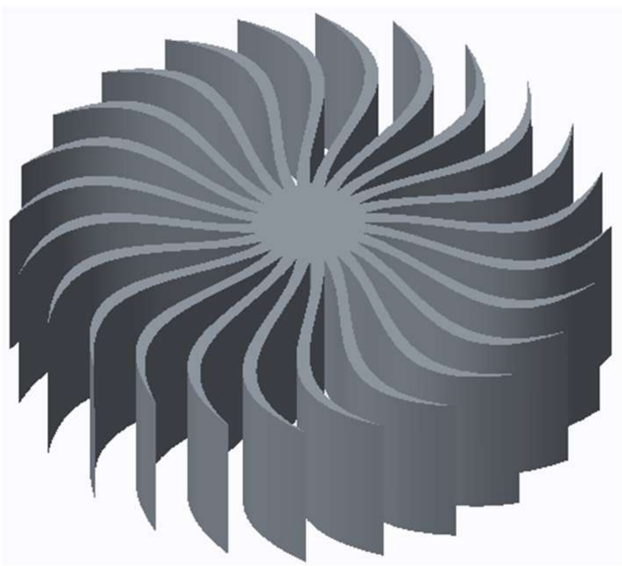

Figure 9: Circular fin

Cons:

- ❖ Difficult to fabricate
- ❖ Won’t efficiently cover semiconductors
- ❖ Fins need to be taller to compensate for decrease in contact area

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Concept: Circular Pin Fin

Pros:

- ❖ Easy to fabricate
- ❖ Low pressure drop
- ❖ Air flow more efficient

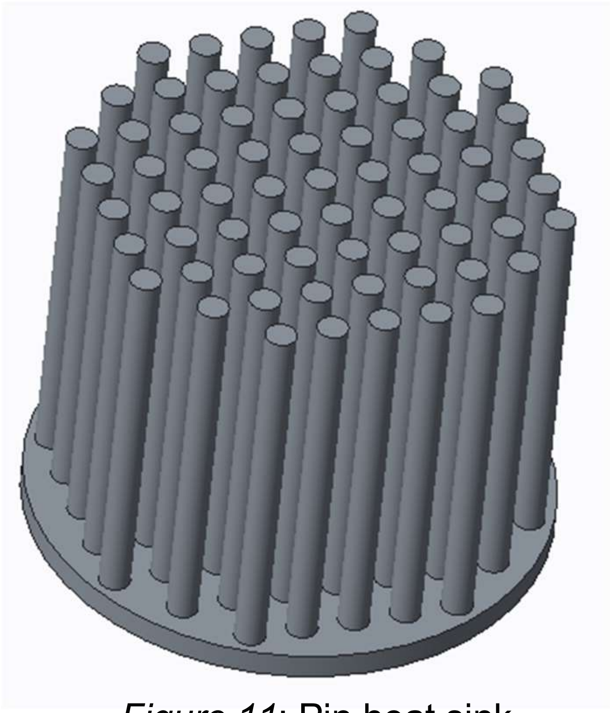

Figure 11: Pin heat sink

Cons:

- ❖ Hard to mount fan
- ❖ Won't efficiently cover semiconductors
- ❖ Pins need to be taller to compensate for decrease in surface area
- ❖ Heavier design

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Concept: Square Corrugated Fin

Pros:

- ❖ Square heat sink with corrugated/wavy fins
- ❖ Fin shape creates larger surface area
- ❖ Fan easily mounted onto heat sink
- ❖ Hot air escapes via buoyant forces
- ❖ Easy diode arrangement

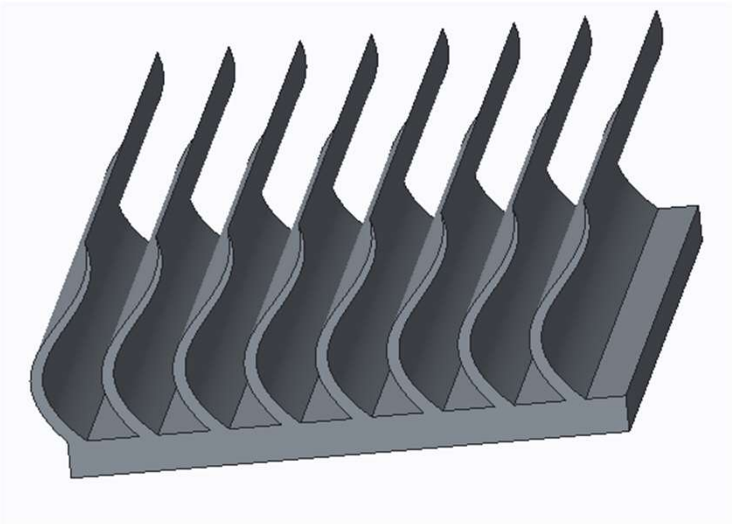

Figure 12: Corrugated fins

Cons:

- ❖ Difficult to fabricate
- ❖ Difficult to repair

Jeffery Rutledge

References

- ❖ Sandia National Laboratories. *The Sandia Cooler.* Retrieved From: https://ip.sandia.gov [1]
- ❖ Walker, Kevin. (2017). *Optimized Power Regulator Cooling* [PowerPoint slides]. [2]
- ❖ Shih WH, Chiu WC, Hsieh WH. *Height Effect on Heat-Transfer Characteristics of Aluminum-Foam Heat Sinks.* ASME. *J. Heat Transfer.* 2005;128(6):530-537. doi:10.1115/1.2188461. [3]