EML4551

Unison Industries Forced Air-Cooled Heat Sink

Parker Harding, Tyler Pilet, and Lucas Pye

03/27/2018

Team 19

Dustin Birchall
Lead ME

Lucas Pye
Web-Developer

Parker Harding
Team Leader

Jeffery Rutledge
Financial Advisor

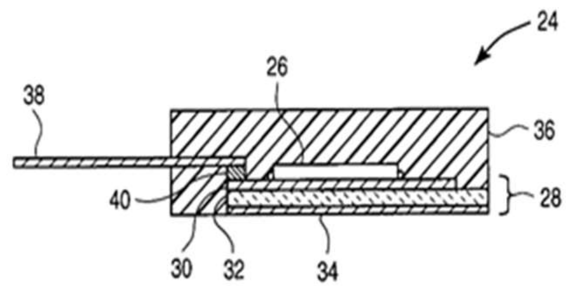
Tyler Pilet
Lead FEA Engineer

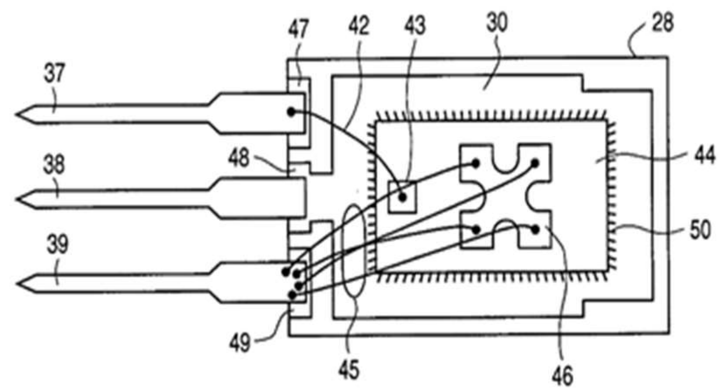
Recap

Parker Harding

Project Recap

- Unison Industries has sponsored our Senior Design team to design and experimentally validate a forced air-cooled heat sink
- The heat sink will be used to maintain 24 semiconductors below max operating junction temperature (150 C)
- Semiconductors output 12.5 W a piece,and are used in aircraft to rectify 3-bridge AC to DC





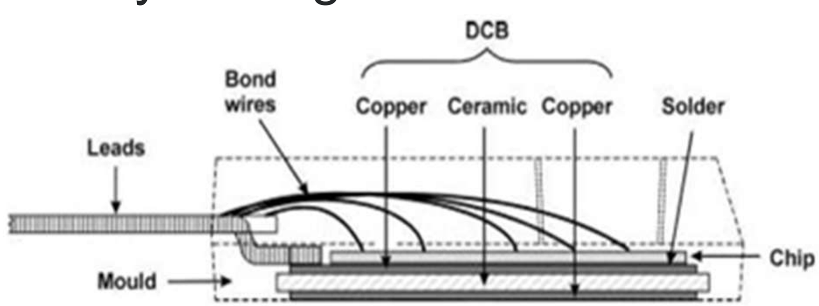
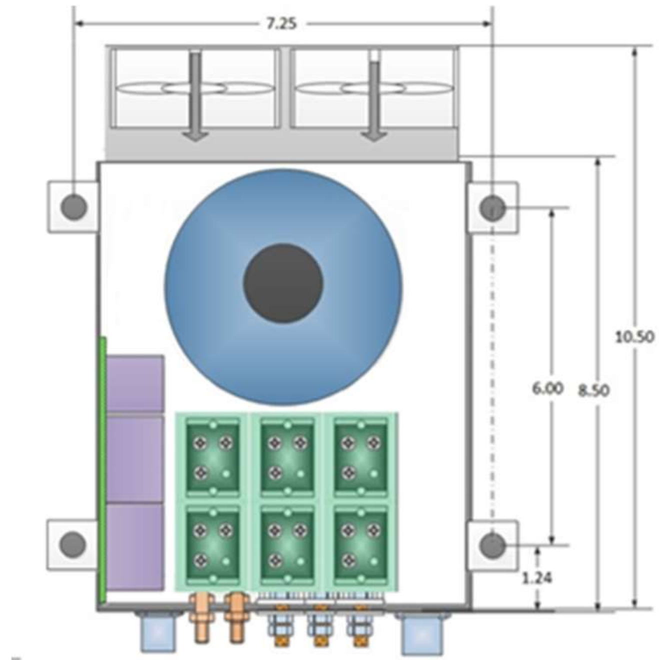


Figure 1: Cross section of an ISOPLUS™ package

Parker Harding

Project Recap

- Goal For Project
  - Create a heatsink that is optimized by minimizing its weight
  - Account for an 85 C ambient temperature
  - Arrange semiconductors in sets of 3
  - Maintain the semiconductors steady state temperature at 135 C



Parker Harding

Heat Transfer

- Methods of Heat Transfer
  - Conduction - Transfer of energy from the more energetic particles of a substance to the less energetic ones as a result of interactions between the particles
    - Fourier's Law of Heat Conduction - $\dot{Q} = -kA(dT/dx)$
  - Convection - Mode of heat transfer between a solid and a liquid or gas, and this method involves a combination of conduction and fluid motion
    - Newton’s Law of Cooling - $\dot{Q} = hA_s(T_s - T_{amb})$
  - Radiation - Energy emitted by matter in the form of electromagnetic waves as a result of the electronic configurations of the atoms or molecules
    - Net Boltzmann's Law of Radiation - $\dot{Q} = \varepsilon\sigma A_s(T_s^4 - T_{amb}^4)$

Parker Harding

Convection Heat Transfer

$$\dot{Q} = hA_s(T_s - T_{amb})$$

- h - Convection Heat Transfer Coefficient
  - Found using the dimensionless Nusselt number
    - $Nu = (hL_c)/k$

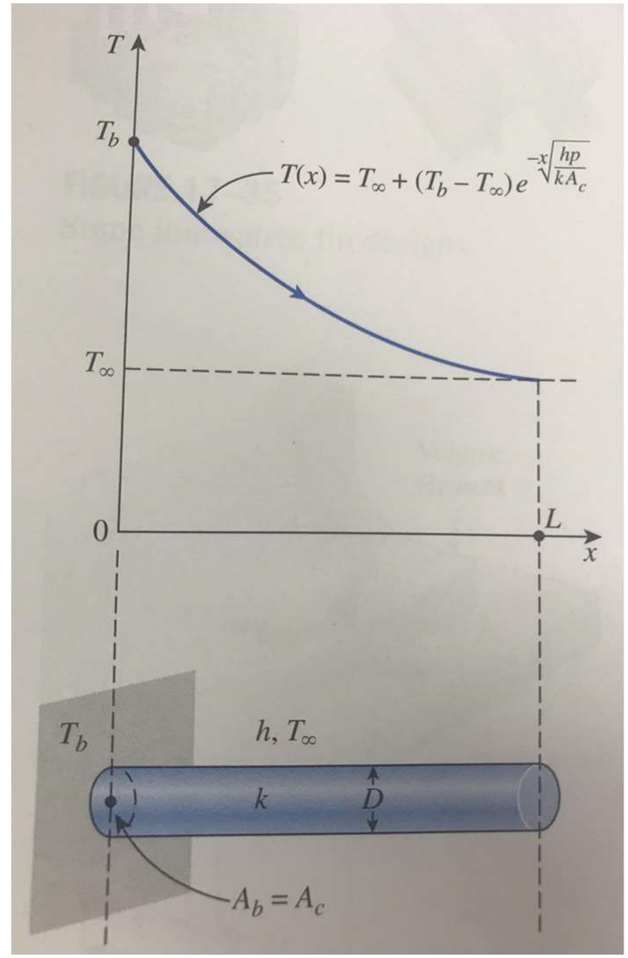
- The general correlation to solve for Nu is follows
  - $Nu = CRe^nPr^m$
    - where C, m, and n are constants based upon certain conditions
      - Duct Shape
      - Flow Regime
      - Heat Flux

Parker Harding

Fin Equation

- Start with the common sense that during steady state the heat conducted into any section of the heatsink is equal to the heat exiting the section in convection and conduction
  - In equation form this looks like : $(d^2T/dx^2) - (hp/kA_c)(T-T_{amb})$

- If the fin is much longer than it is wide, then one can solve this ODE to find a temperature profile of the fin
  - $T(x) = T_{amb} (T_{base}-T_{amb})e$^$(-x(hp/kA_c)$^(½))



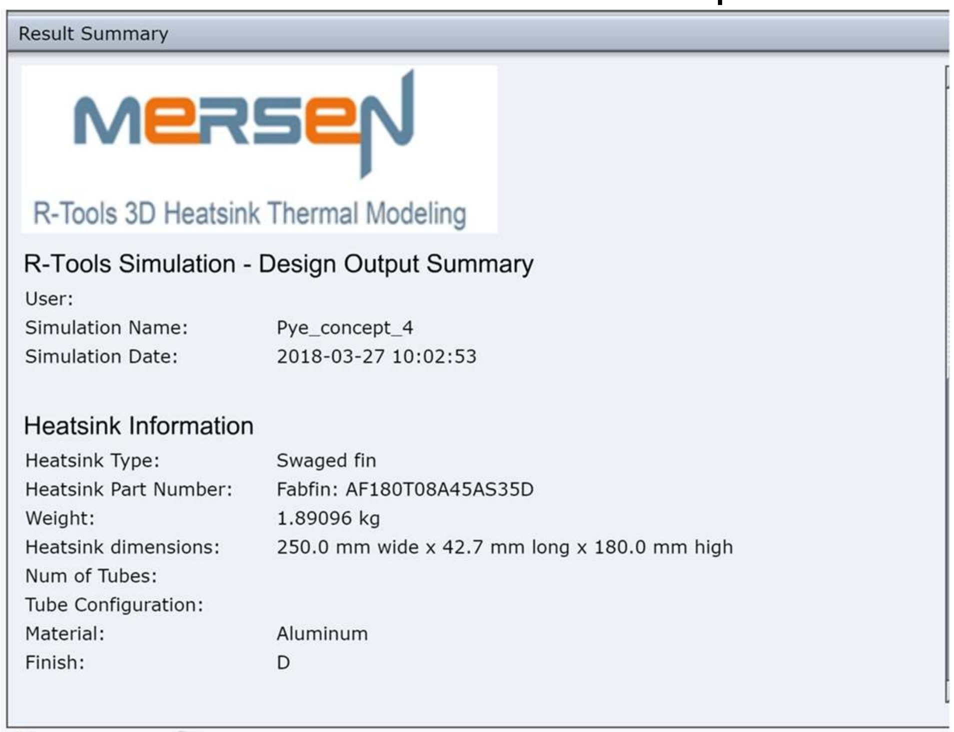
Parker Harding

Methods

Lucas Pye

Benchmarking

- Sponsor never specified a specific weight constraint, only to make it as light as possible.
- In order to determine acceptable maximum for weight, we benchmarked from R-theta (industry standard).
- R-theta provided us with a minimum heat sink option of 1.89 kg or roughly 4 lbs.


Result Summary

MERSEN

R-Tools 3D Heatsink Thermal Modeling

R-Tools Simulation - Design Output Summary

User:	
Simulation Name:	Pye_concept_4
Simulation Date:	2018-03-27 10:02:53

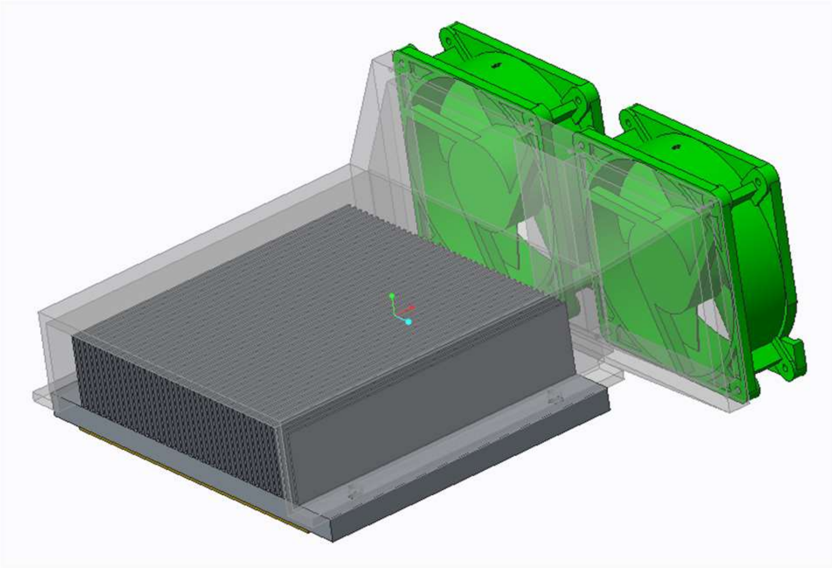
Heatsink Information

Heatsink Type:	Swaged fin
Heatsink Part Number:	Fabfin: AF180T08A45AS35D
Weight:	1.89096 kg
Heatsink dimensions:	250.0 mm wide x 42.7 mm long x 180.0 mm high
Num of Tubes:	
Tube Configuration:	
Material:	Aluminum
Finish:	D

Lucas Pye

Design Selection

- Main design selection motivations were cost, time, and durability.
- We want to keep the design rectangular since they are easy to manufacture and will give us more time to test.
- We modeled our design from the heat sink given by R-theta: A rectangular fin forced air convection heat sink.
- Our final design implemented a different spacing between fins in order to save approximately $400.

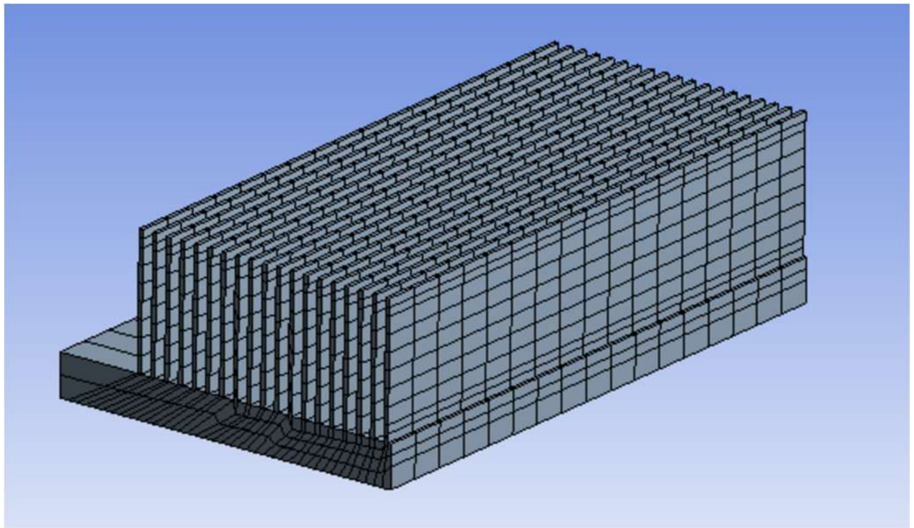


- Things to note:
  - Dual Fans
  - Ducted Air
  - Aluminum Body

Lucas Pye

FEA Analysis

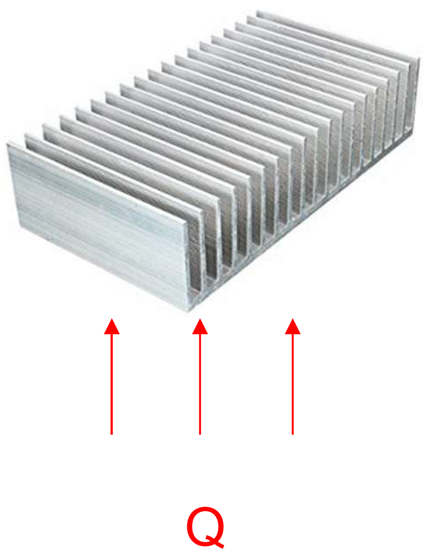
- Finite Element analysis (FEA) breaks down a component into many small parts using meshing and then, given boundary conditions, observes the relationship between the many components at steady state.
- The mesh on the right is from ANSYS. They have limitations on their student program that restricts us to a coarse mesh.
- More mesh nodes means a more accurate simulation.



Lucas Pye

Experimental Validation (Future)

- In order to make sure our results from ANSYS are accurate, we must validate it experimentally.
- Resistors will provide our heat flux in place of the semi-conducting chips (much less money).
- We will use a thermal imaging camera to provide us with a visualization of how the heat is being displaced within the heat sink.



Lucas Pye

Design Optimization (Future)

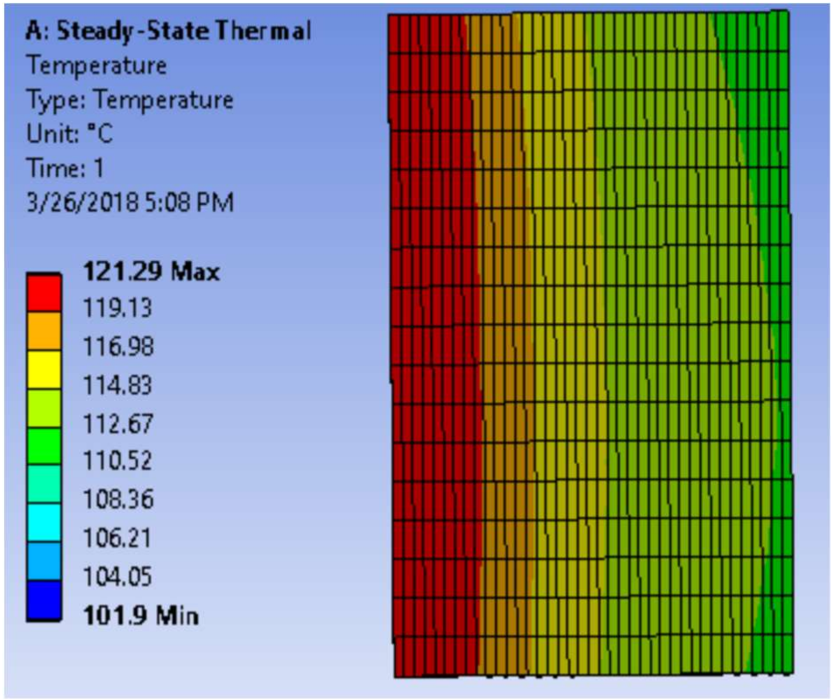
- The final stage of our design will be to fully optimize it.
- We will take the results from the experimental validation to determine which regions of the heat sink are not contributing.
- These regions will be removed via the machine shop.
- Since we ordered 2 heat sinks we do not have to be concerned with potentially cutting too much off.
- We will have a good baseline heat sink and a design which weighs relatively less than baseline without sacrificing performance very much.

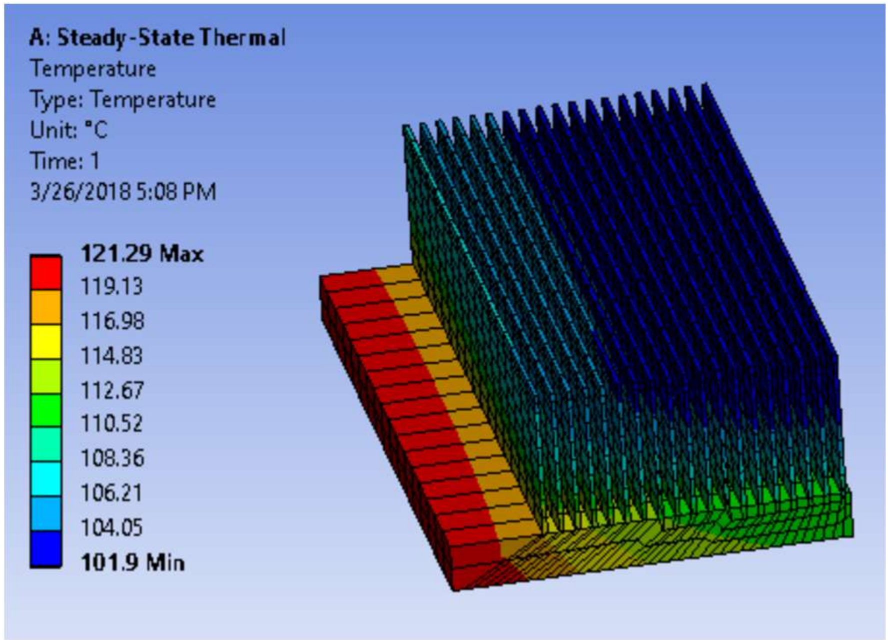
Lucas Pye

Results & Discussion

Tyler Pilet

Old Design (Forced Convection)

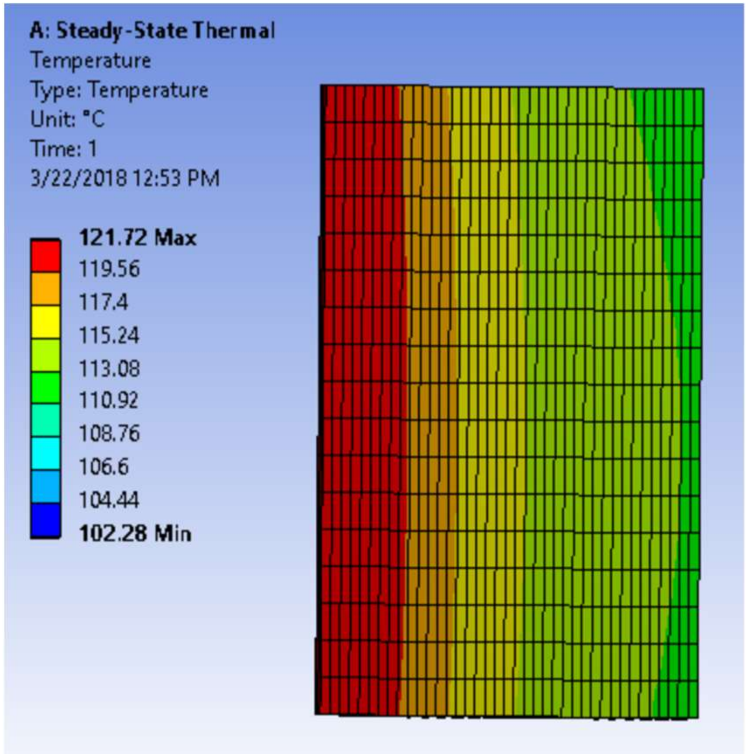


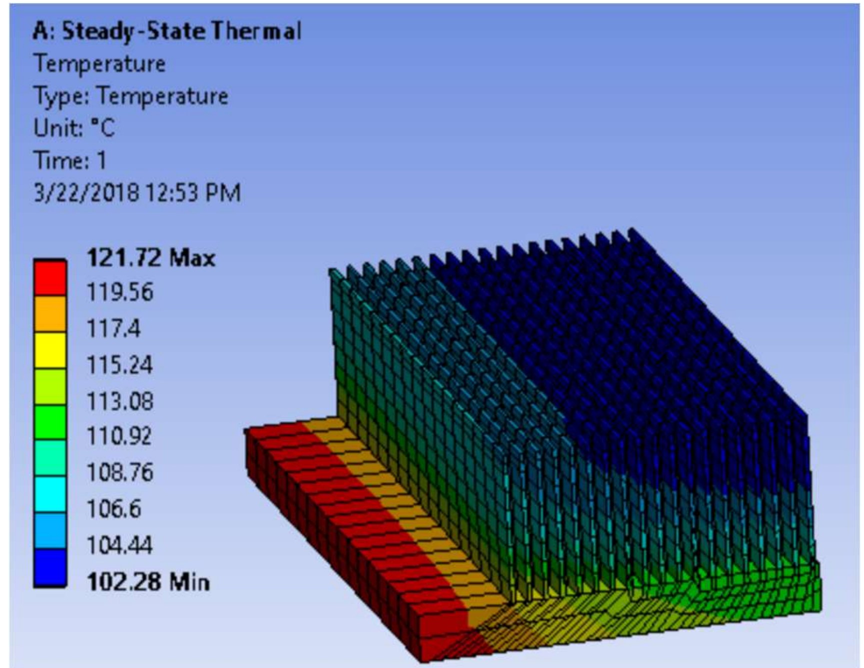


Fin Spacing of 0.133 in

Tyler Pilet

New Design (Forced Convection)

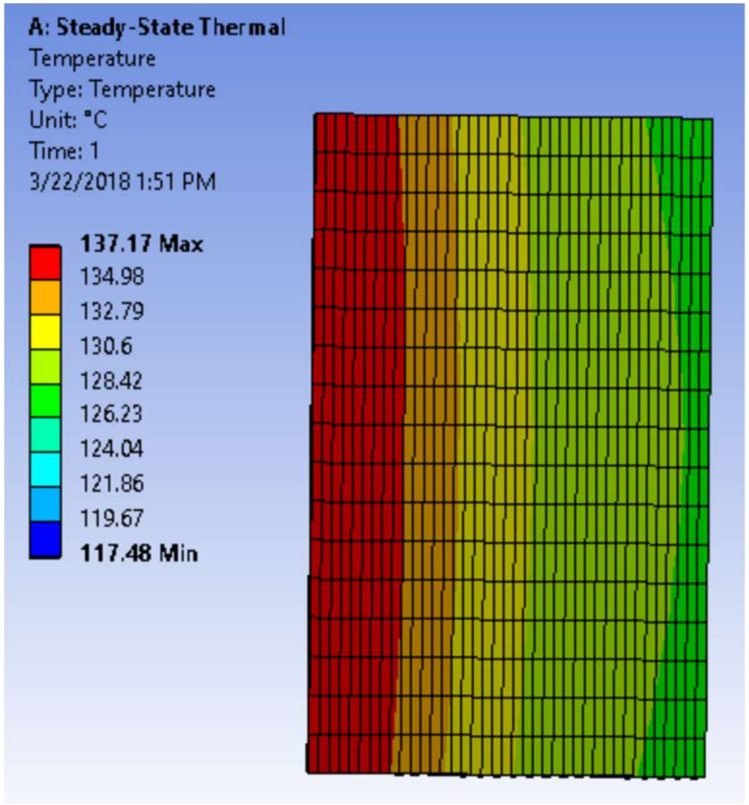


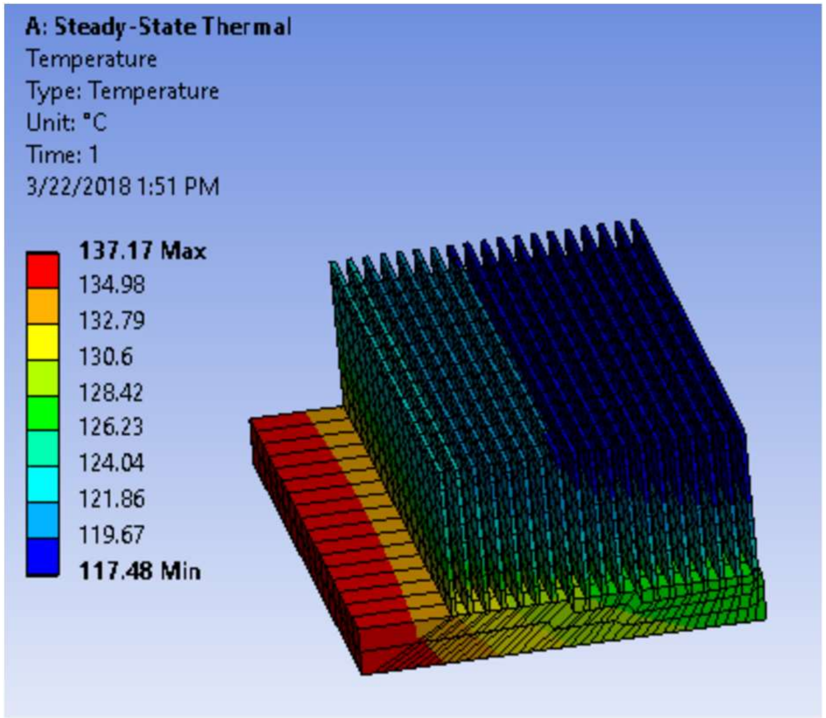


Fin Spacing of ~~0.133~~ in
0.125

Tyler Pilet

New Design (Natural Convection)



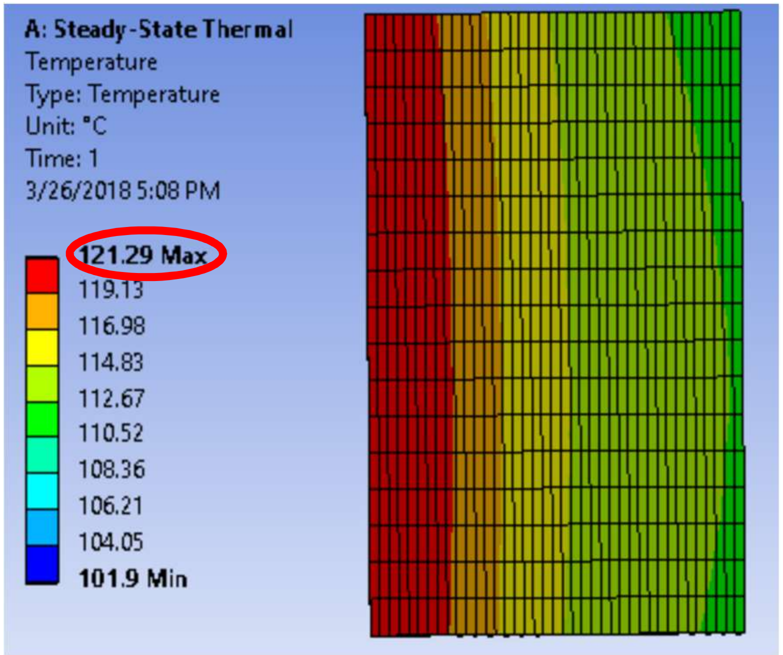


Tyler Pilet

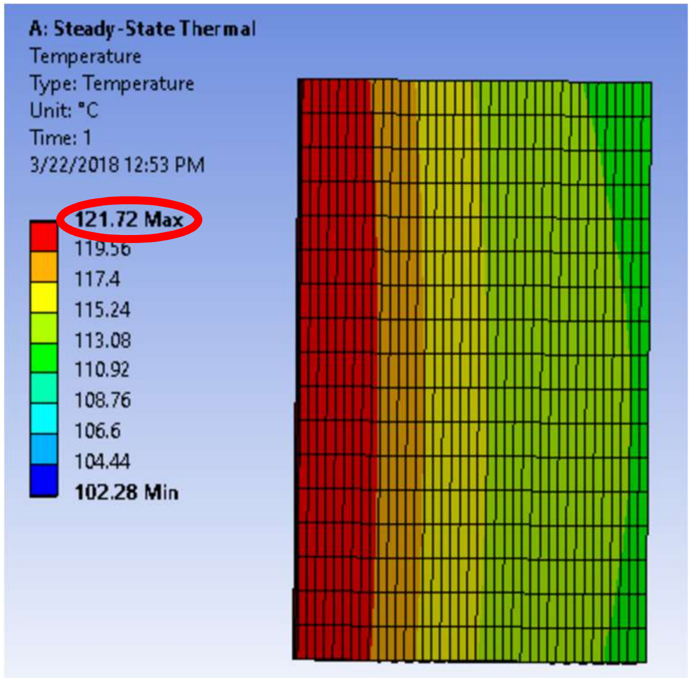
Discussion

- The design change of fin width from 0.133 in to 0.125 in resulted in a 0.43°C (121.29°C to 121.72°C) increase in max temperature, but saved our team $400. This project would not have been under budget without the design change.

Old



New

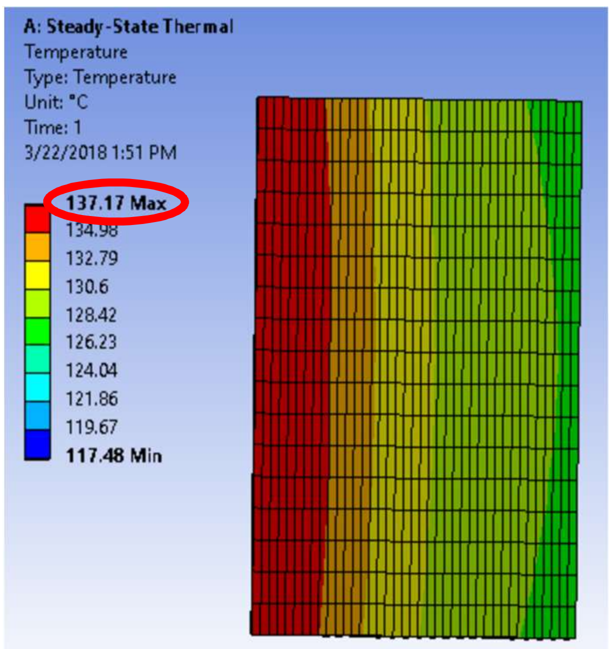


Tyler Pilet

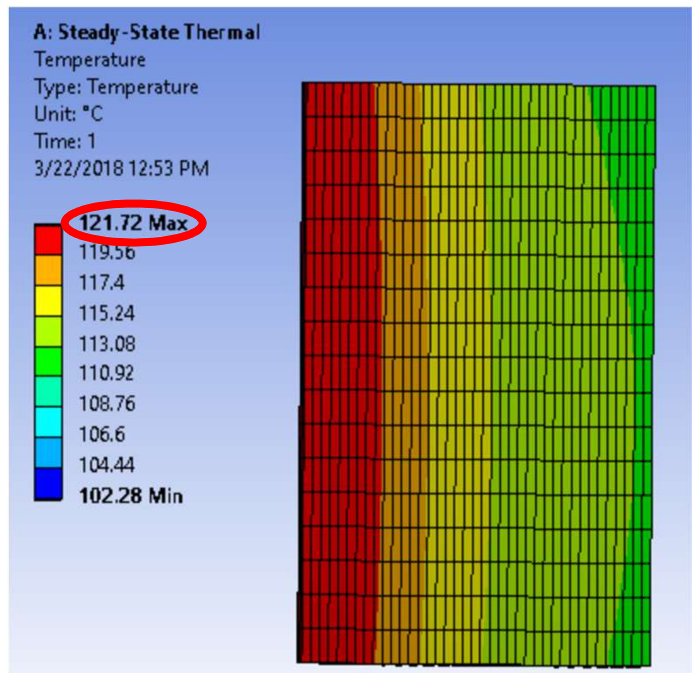
Discussion (cont.)

- Our team initially discussed designing a heat sink for natural convection rather than forced convection, but adding forced convection increased thermal performance by 15.4°C (137.14°C to 121.72°C).

Natural Convection



Forced Convection



Tyler Pilet

Budget

- Total Budget: $2,000
- Current running total spent: $1,834.30
- Current running total left: $165.70

Website	Purchase	Quantity	Cost	Running Total Cost	Running Total Budget
https://www.alliedelec.com/caddock-mp915-20-0-1-/70089556/	Resistors	30	$52.20	$52.20	$1,947.80
https://www.mcmaster.com/#fans/=1bdtg5n	Fans	2	$146.84	$199.04	$1,800.96
https://www.velocitymachineworks.com/	Machine Work	2	$1,584.38	$1,783.42	$216.58
https://www.alliedelec.com/rs-pro-7074604/70647774/	Thermal Sheet	4	$50.88	$1834.30	$165.70

Current Budget for Team 19

Tyler Pilet

References

- R-Theta "Mersen" Retrieved From: www.mersen.com
- Cengel, Yunus. *Fundamentals of Thermal Fluids Sciences*
- ANSYS Student Edition V.19.0

QUESTIONS?