University of New Haven

PROJECT

MECH – 6632

APPLIED CONDUCTION HEAT TRANSFER

Professor – George Bauer

PCB STEADY STATE HEAT TRANSFER OPTIMIZATION

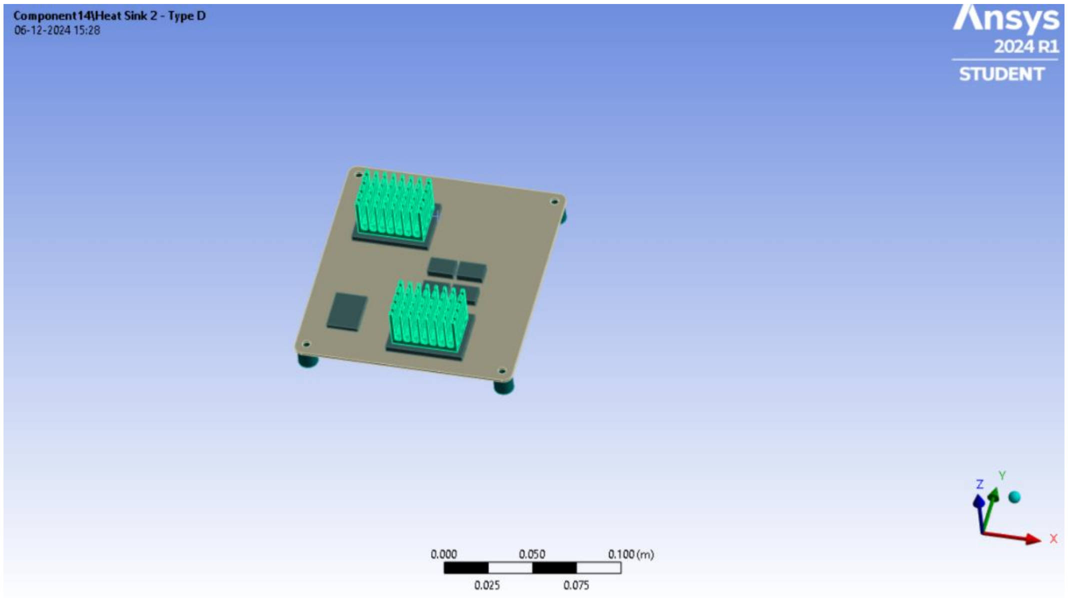
Final Design & Analysis Project

By

Yashwanth Kanthala (00921675)

CONTENT

BASE ITERATION (TYPE D)



Heat Sink (Type D): This is likely a bigger structure made of metallic fins for dissipating heat generated by the internal components.

Processors (1 and 2): They are rectangular blocks, probably with heat spreaders, which are most likely the device main processing units and handle computations of the device.

Chips (1 thru 5): These are smaller rectangular components that may be memory chips or other specialized circuits.

Standoffs: These likely small cylindrical elements are spacers or isolators between various parts of the assembly.

Board: The bottom structure that holds all components together, likely above the heat sinks.

Material Composition:

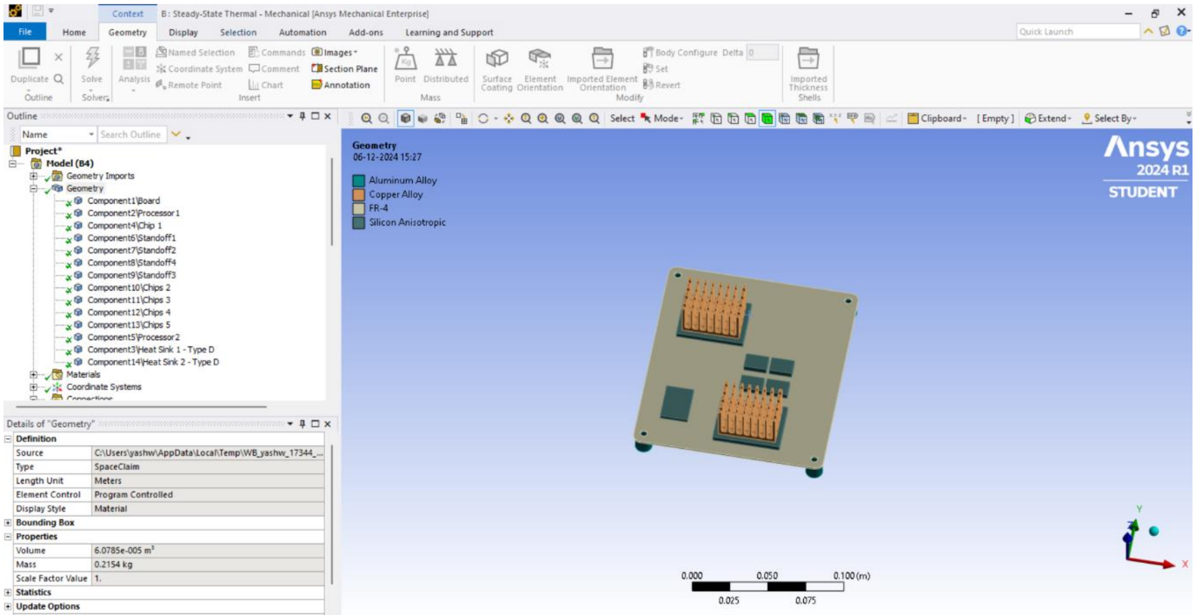
The model appears to be made up of many different materials:

Aluminum Alloy: Perhaps used for the heat sinks because of its excellent thermal conductivity.

Copper Alloy: Maybe heat spreaders or other components for which high electrical conductivity is a design requirement.

FR-4: This is a usual material for printed circuit boards (PCB).

Silicon Anisotropic: Chips are most likely made of it, known for their semiconductor properties.

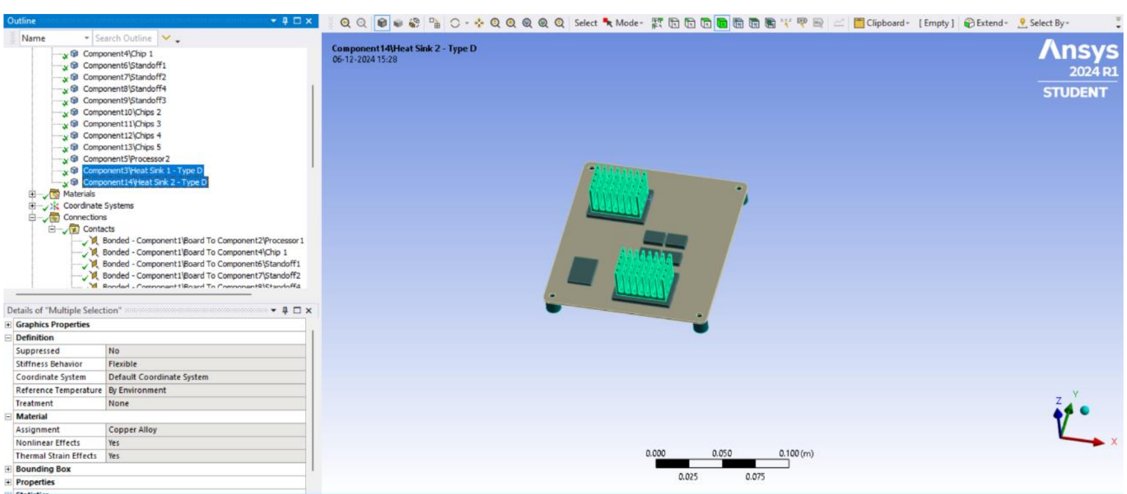


There are three types of heat sinks generally being used.

These are manufactured by extruding aluminum or copper through a die-a process permitting a variety of shapes and sizes of fins. They are normally used for general-purpose cooling.

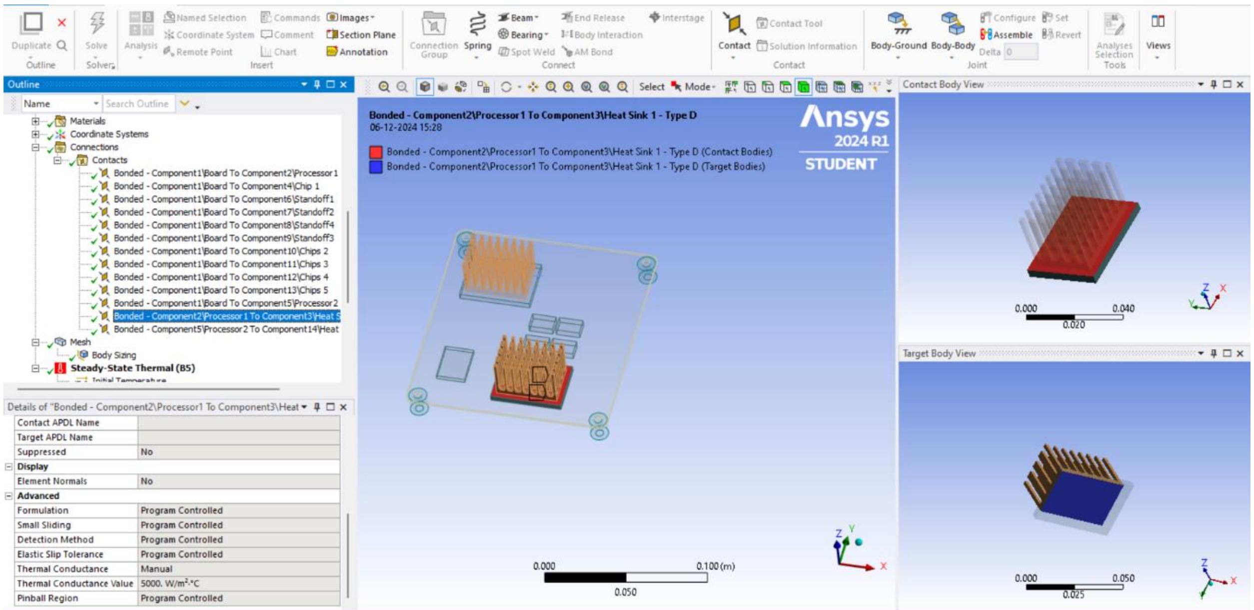
These heat sinks consist of a base plate with fins attached to it using thermal adhesive, most often used for high-power applications.

This type of heat sinks consists of a series of parallel plates that have fins attached to them, and they are usually used for high-performance purposes.

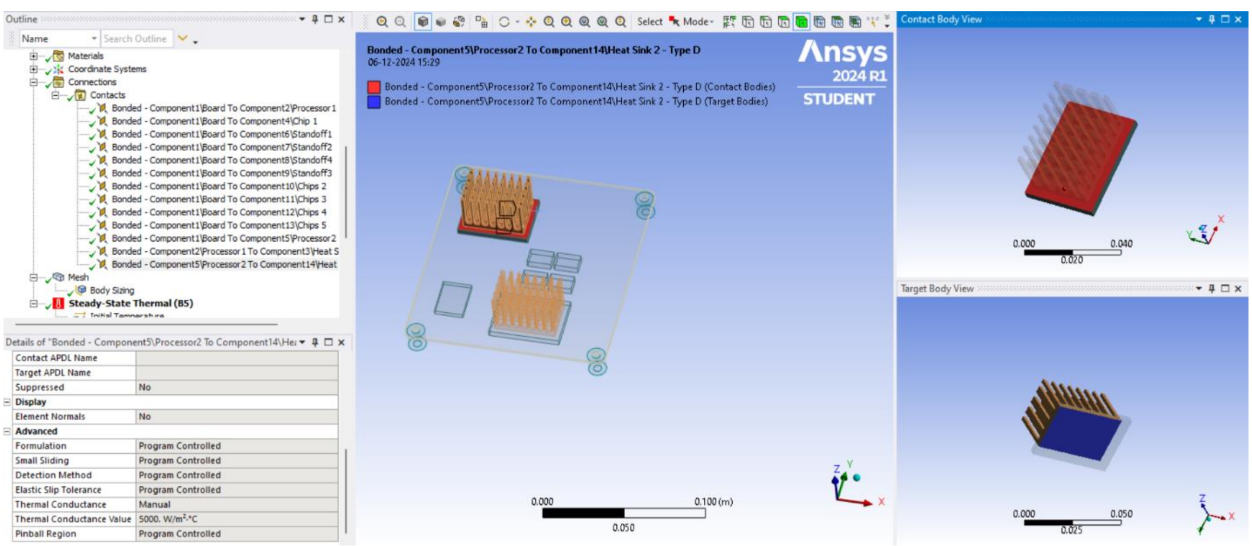


THERMAL CONDUCTANCE TO HEAT SINK 1

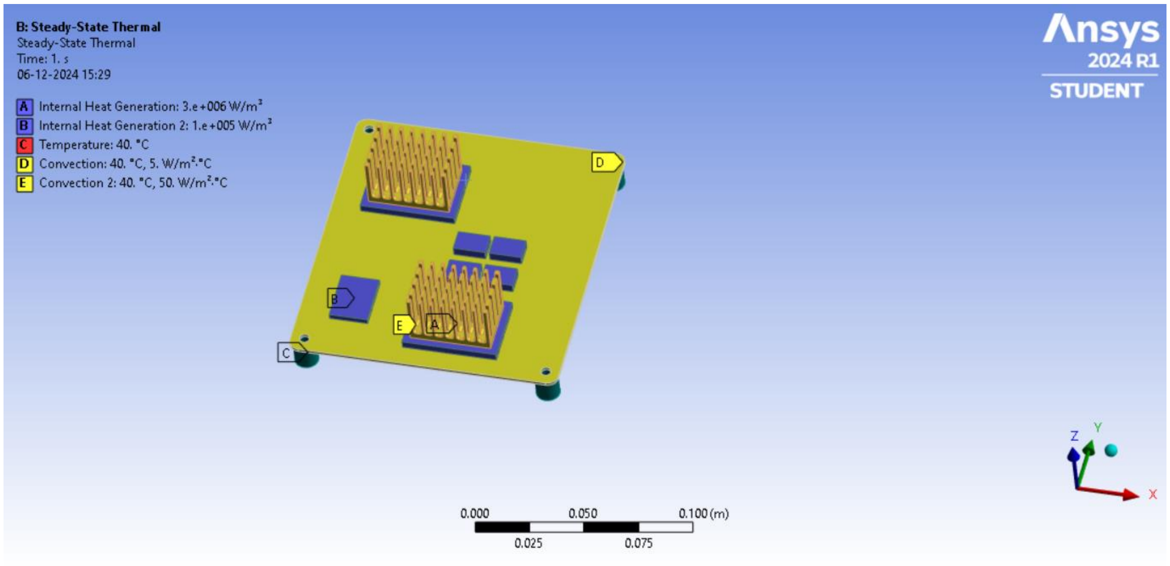
In this we used the bonded contact between the heatsink and the the conductance material . we used the thermal conductance as 5000 W/M^2 C for both the heat sinks.



THERMAL CONDUCTANCE TO HEAT SINK 2



Steady-State Condition: In steady state, the heat generated internally is balanced by the heat dissipated through convection and fixed boundaries, leading to a stable temperature field



A: Internal Heat Generation (3.0×10^6 W/m^3)

B: Internal Heat Generation (1.0×10^5 W/m^3)

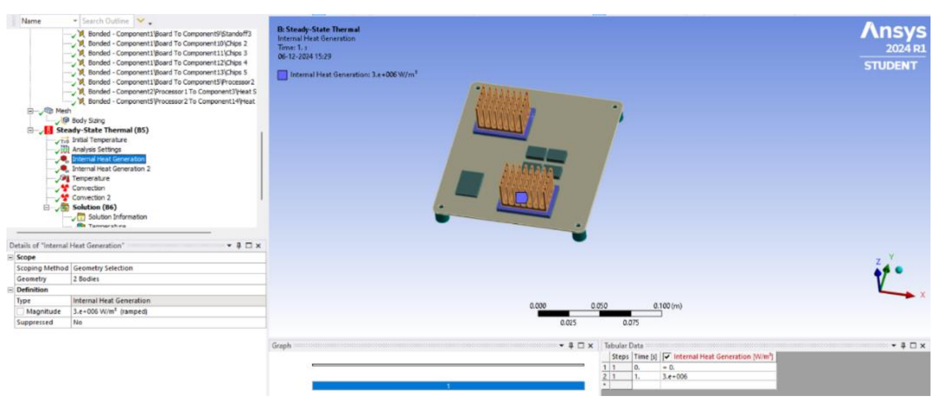
C: Temperature Constraint (40°C)

D: Convection (40°C, 5 W/m^2·°C)

E. Convection (40°C, 50 W/m^2·°C)

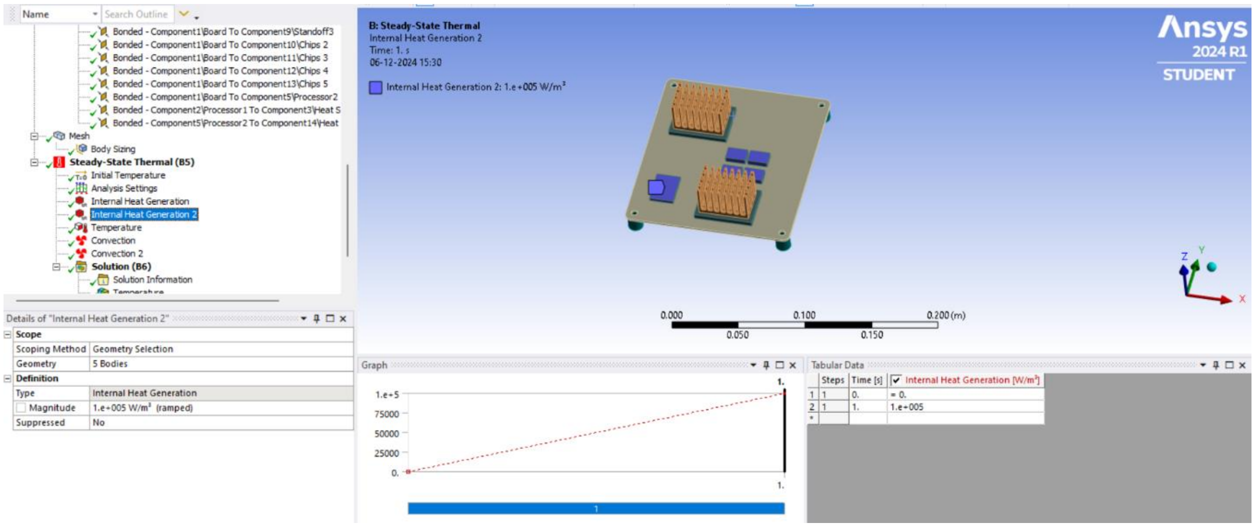
Internal Heat Generation (3.0×10^6 W/m^3)

In this we used internal heat generation to two processors 3.0×10^6 W/m^3**.**Represents a localized area, likely electronic components or processors, generating high heat internally due to operational power dissipation.



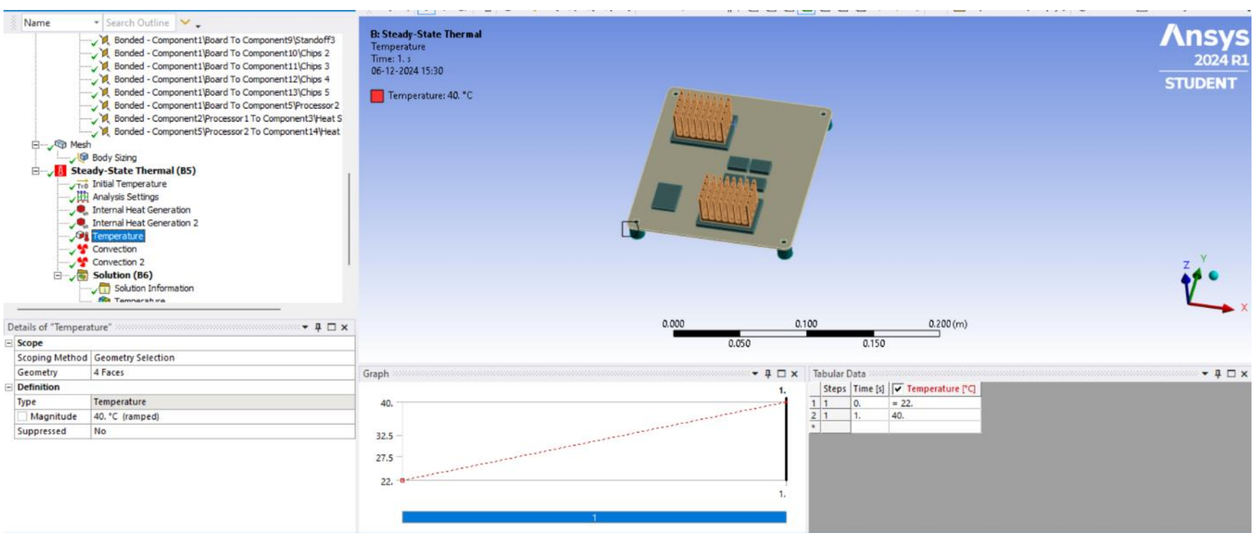
B: Internal Heat Generation (1.0×10^5 W/m^3)

Indicates a region with lower internal heat generation, possibly less active components or materials with lower power usage.



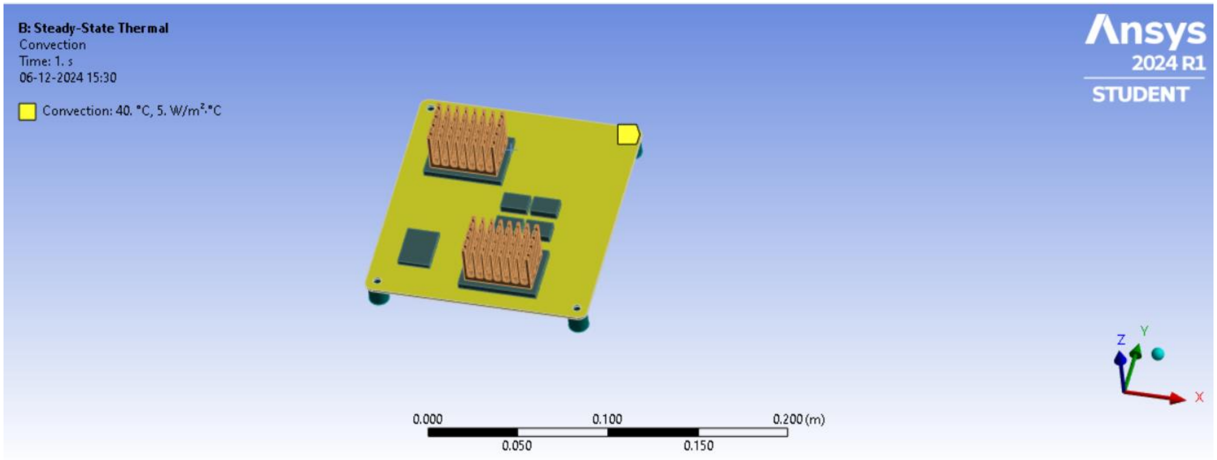
C: Temperature Constraint (40°C)

A fixed temperature boundary, such as a heat sink or a cooling interface, ensuring the area remains at a constant temperature of 40°C.



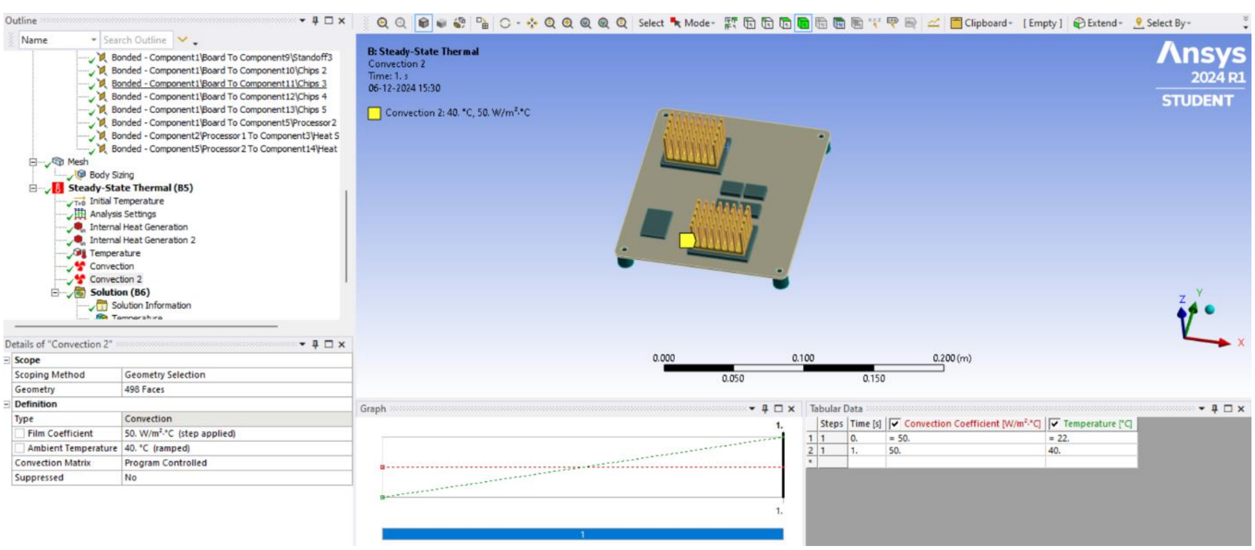
D: Convection (40°C, 5 W/m^2·°C)

A convective boundary condition with a convective heat transfer coefficient of 5 W/m^2·°C at 40°C, implying a surface losing heat to surrounding air.



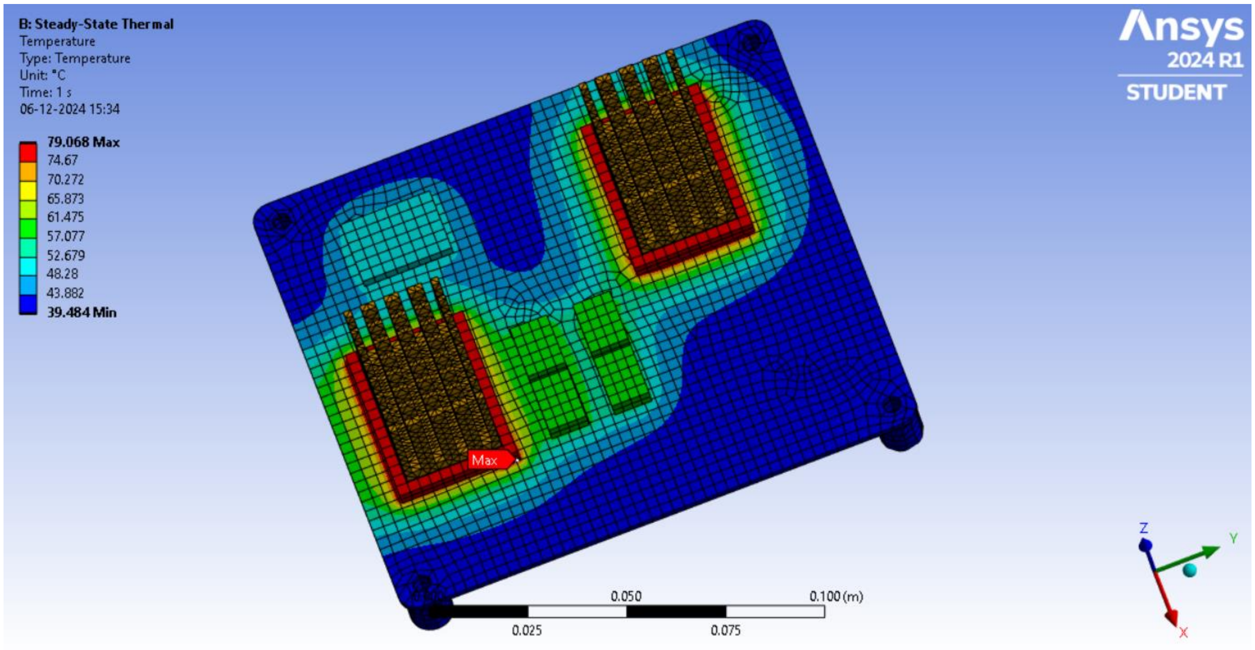
E: Convection (40°C, 50 W/m^2·°C)

Indicates a stronger convective heat transfer (50 W/m^2·°C) compared to D, possibly due to forced convection or a different cooling method.(better h= 50 W/m^2·°C=$15)



TEMPERATURE DEFORMATIOM:

Here the temperature is below the 80 C so it satistys the customer satisfaction. It has a temperature of 79.068 max at the processer and minimum of 39.484 C . I thnk it satisfys the given conditions .



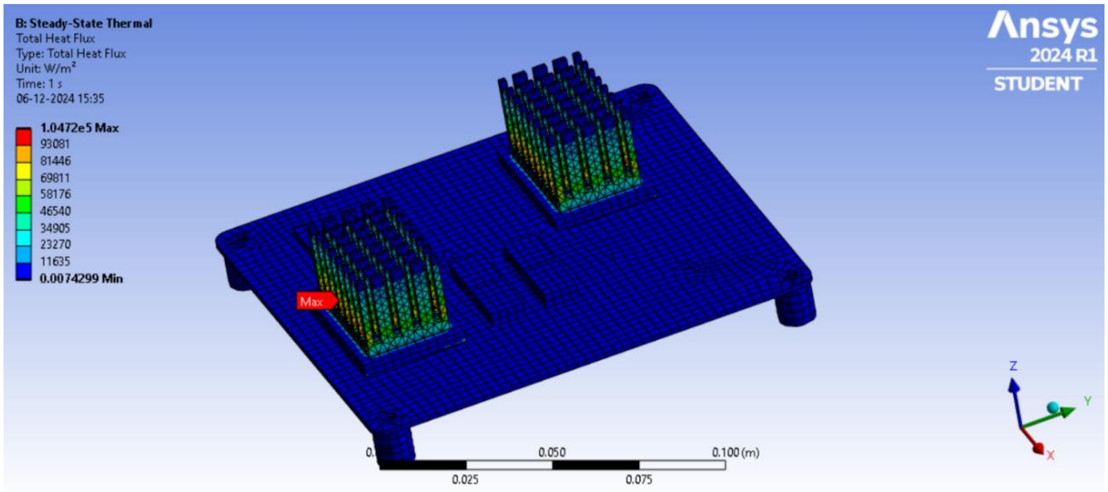
The thermal energy flux is very concentrated through the heatsink areas (colored in red, yellow, and green) specifically at the fins where convection is taking away heat to surroundings.

This is confirmed by the red arrow being the maximum heat flux in one of the heatsinks, thus establishing it as the critical thermal zone.

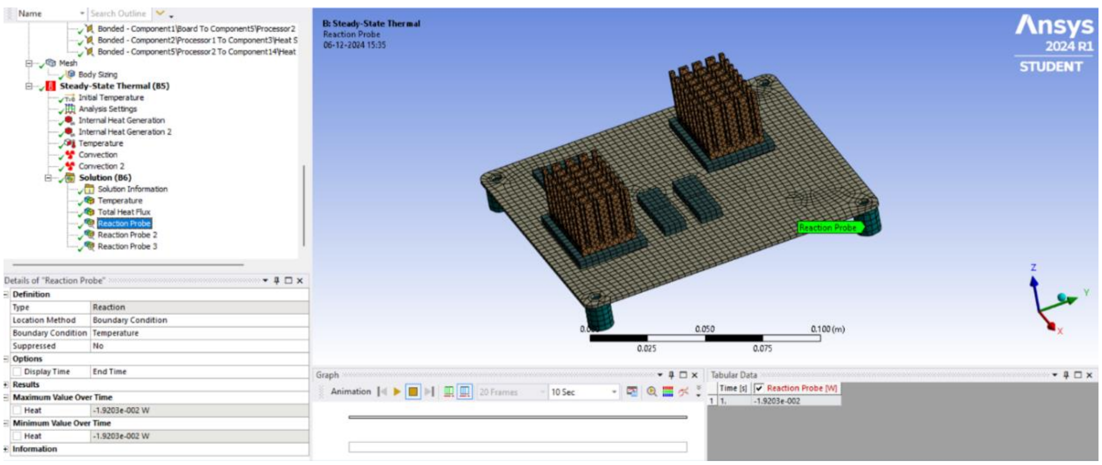
Highest at the base of the heatsinks, where the internal heat is confined.

Gradually decreasing toward the fins, indicating the heat is dissipated by convection

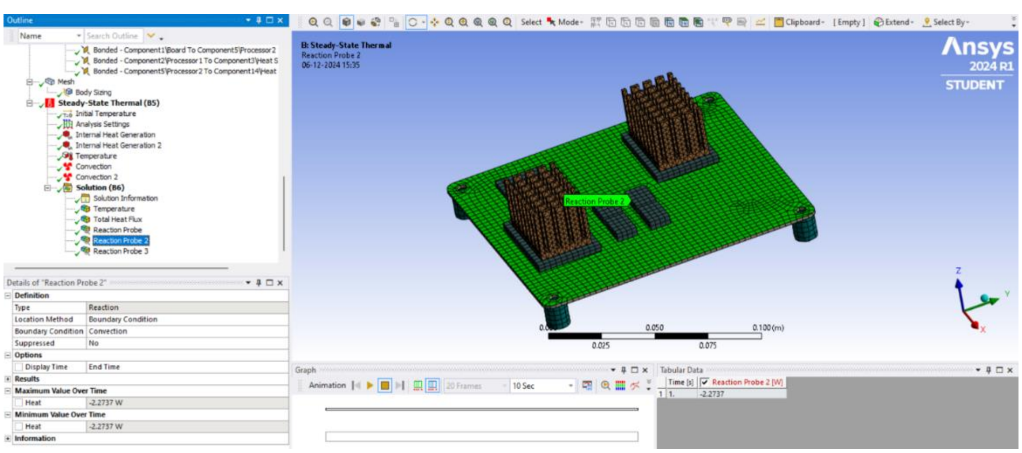
HEAT FLUX CONCENTRATION



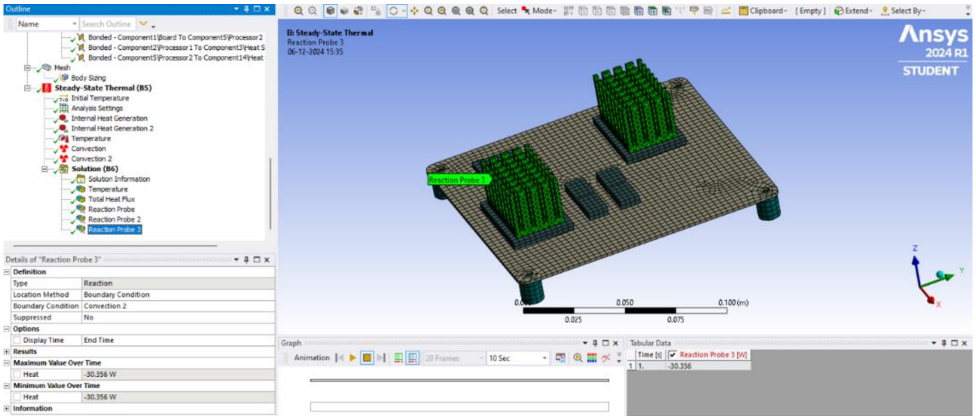
THE REACTION PROBE FOR TEMPERATURE:



THE REACTION PROBE FOR NATURAL CONVECTION:



THE REACTION PROBE FOR FORCED CONVECTION 2



Thermal Conductance = 5000 W/(m^2·°C), Fan = Good (h = 50 W/(m^2·°C)

Total Cost: Thermal Conductance value + fan option

= $25*2+$15

= $ 75

Total Weight: 0.5154 kg

But in this iteration I got the fan weight as 0.2 kg but the given conditions the total weight is 0.5154 kg .In this ieration we reached the temperature below the 80 C by using the good materials. The main reason for increase in the weight because of the material used in this iteration as the copper.

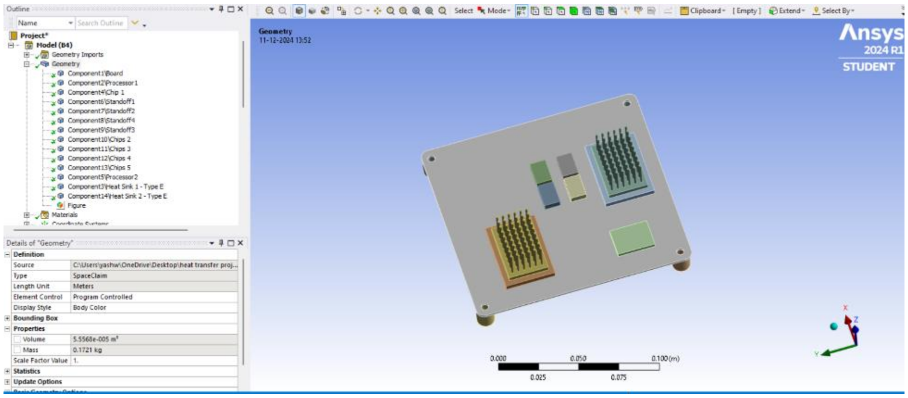
I think the total cost is $40 is a reasonable cost for the customer .

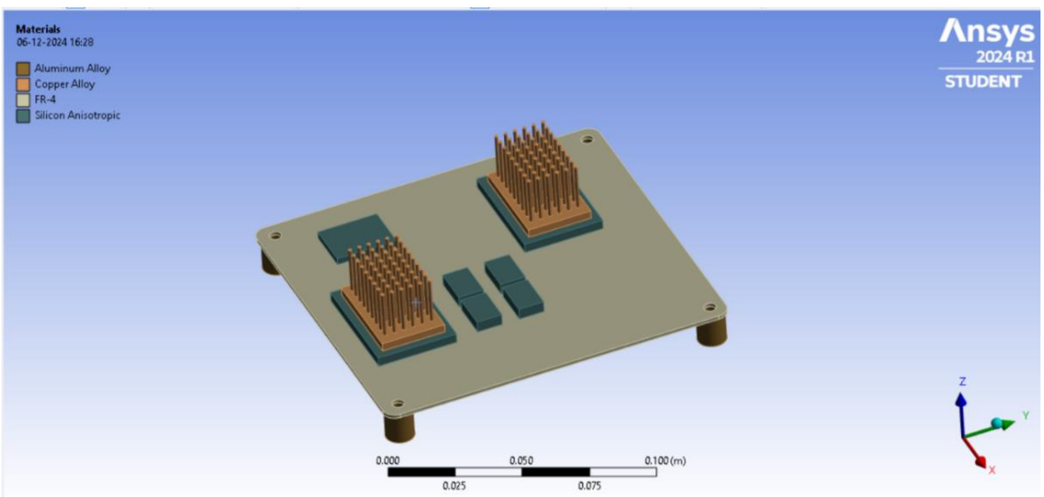
Advantages:

1. **Cost-Effective:** It balances higher performance without the excessive cost of 10000 W/(m^2·°C) conductance or the Better fan.
2. **Moderate Weight:** 0.5154 kg is light enough to not significantly impact the overall system weight.
3. **Performance:** The heat transfer coefficient of 50 W/(m^2·°C) ensures effective cooling, keeping the processor's temperature well below the critical limit of 80°C.

ITERATION 2 (TYPE E)

In this iteration I used heat sink E





Material Composition:

The model appears to be made up of many different materials:

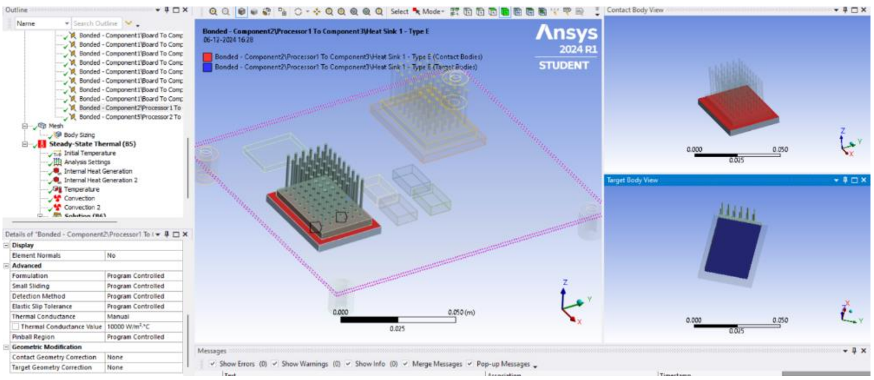
Aluminum Alloy: Perhaps used for the heat sinks because of its excellent thermal conductivity.

Copper Alloy: Maybe heat spreaders or other components for which high electrical conductivity is a design requirement.

FR-4: This is a usual material for printed circuit boards (PCB).

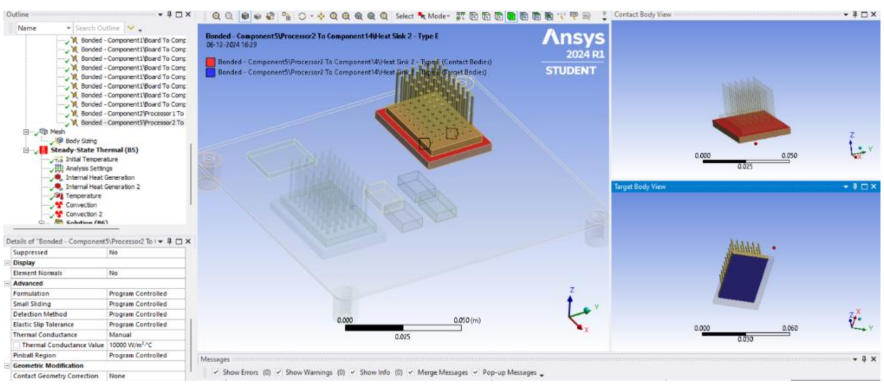
THERMAL CONDUCTANCE TO HEAT SINK 1

In this we used the bonded contact between the heatsink and the the conductance material . we used the thermal conductance as 10000 W/M^2 C for both the heat sinks.

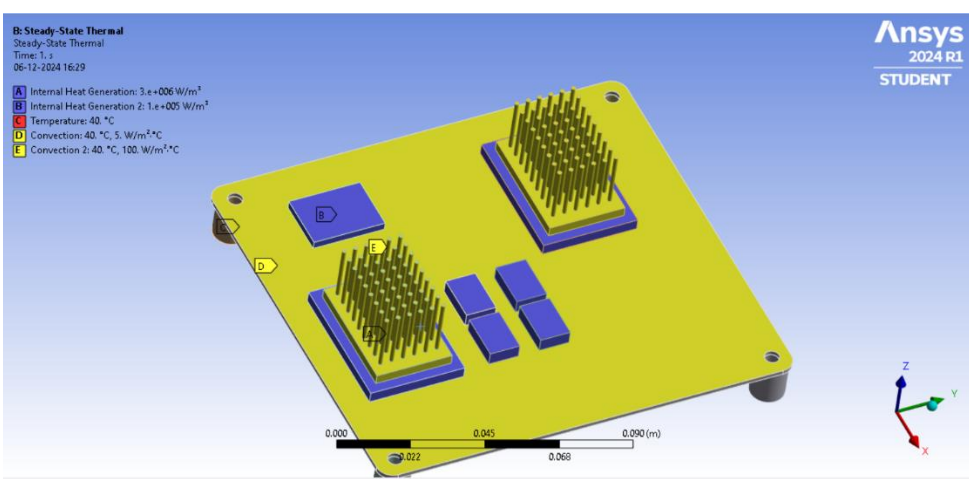


THERMAL CONDUCTANCE TO HEAT SINK 1

In this we used the bonded contact between the heatsink and the the conductance material . we used the thermal conductance as 10000 W/M^2 C for both the heat sinks.



STEADY STATE CONDITION



A: Internal Heat Generation (3.0×10^6 W/m^3)

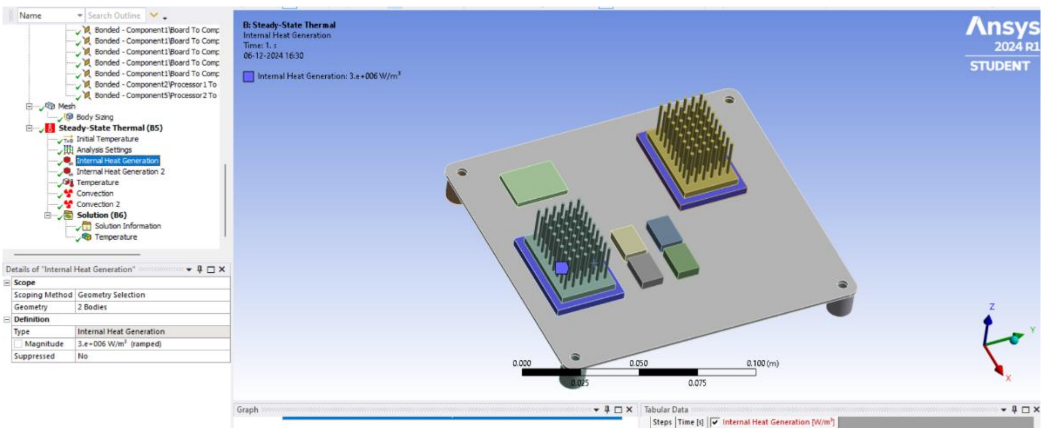
B: Internal Heat Generation (1.0×10^5 W/m^3)

C: Temperature Constraint (40°C)

D: Convection (40°C, 5 W/m^2·°C)

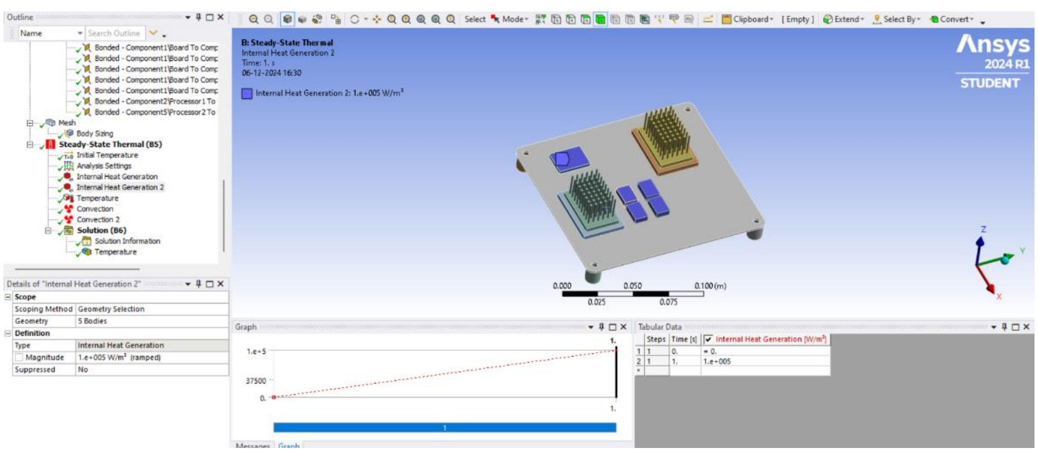
E. Convection (40°C, 100 W/m^2·°C)

INTERNAL HEAT GENERATION



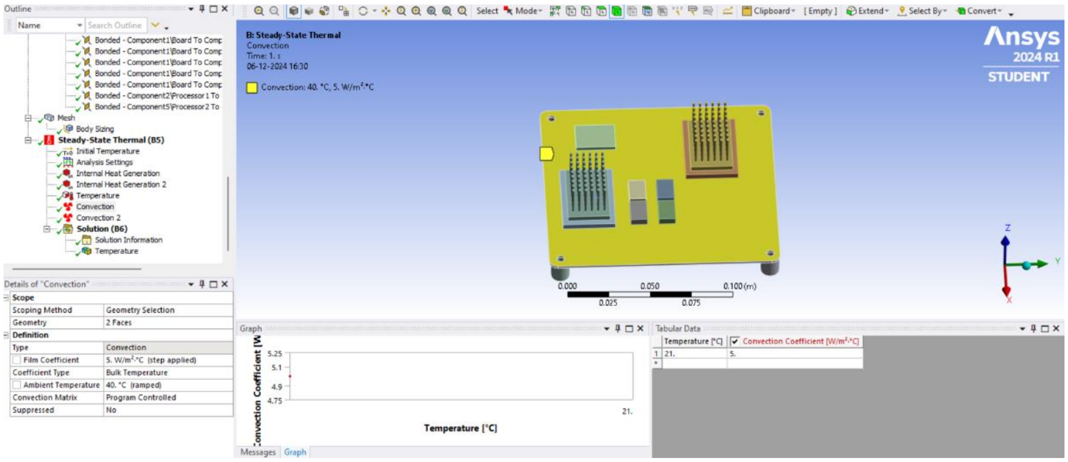
INTERNAL HEAT GENERATION 2

In the steady state conditions we use the internal heat generation for all the five chips as 1.0×10^5 W/m^3.



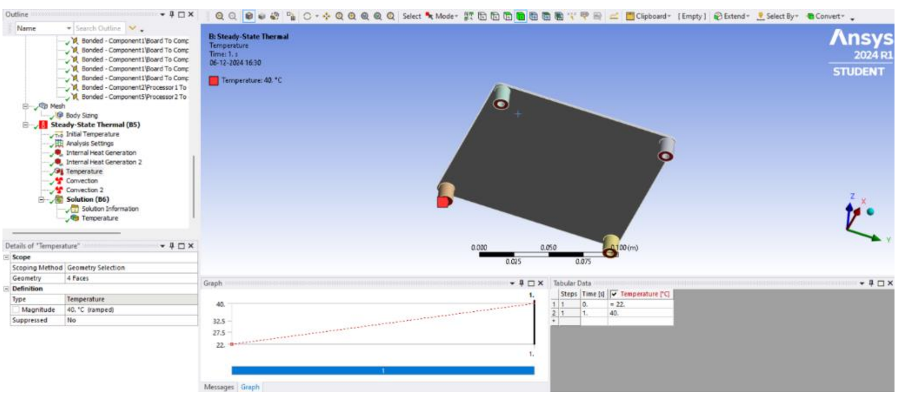
NATURAL CONVECTION

In steady state thermanl analysis this we used natural convection to the 2 surface of the boards 5 W/m^3 at 40 C



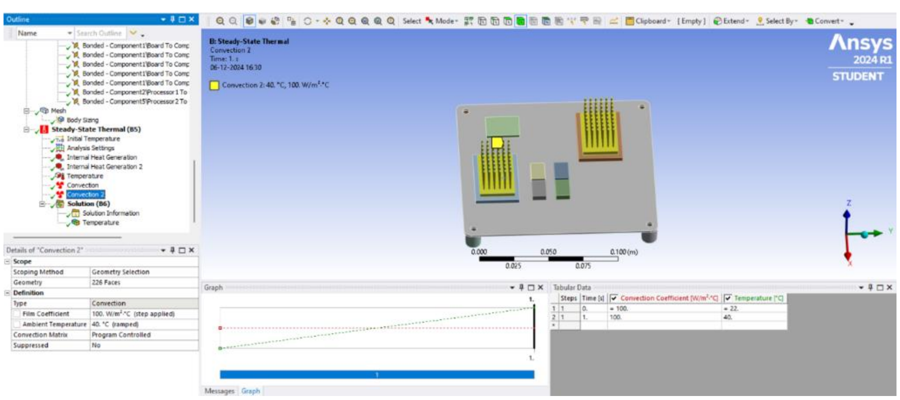
FIXED TEMPERATURE

We used fixed tempertaures for all 4 stands as 40C



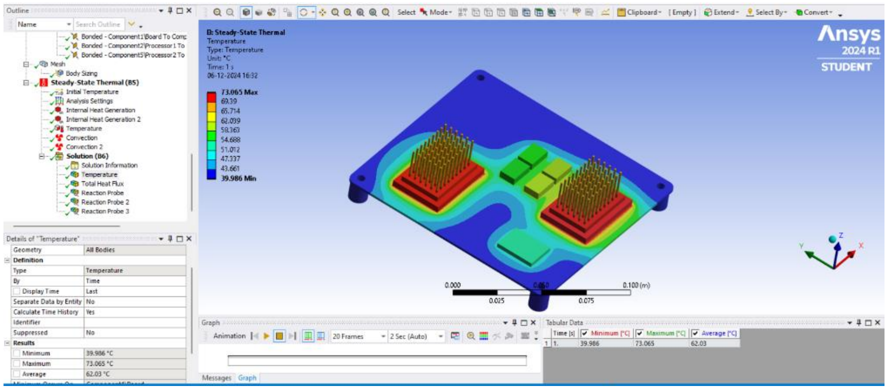
FORCED CONVECTION

We used the force convection of to the both heat sinks h = 100 W/m^{3}C at 40 C



TEMPERATURE DEFORMATION:

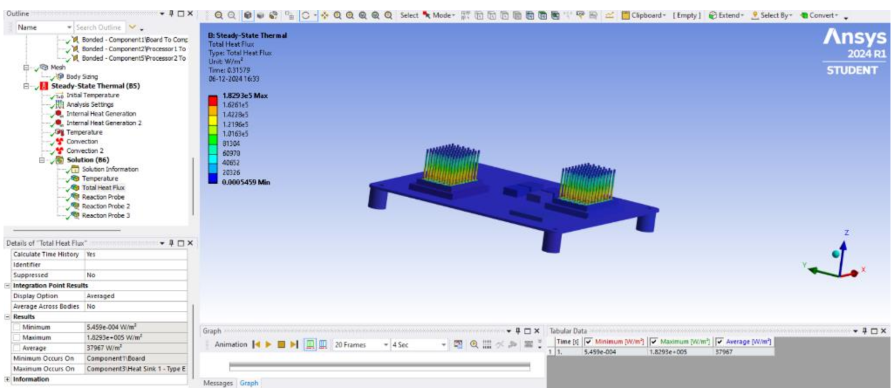
Here the temperature is below the 80 C so it satistys the customer satisfaction. It has a temperature of 73.065 max at the processer and minimum of 39.986 C . I thnk it satisfys the given conditions .



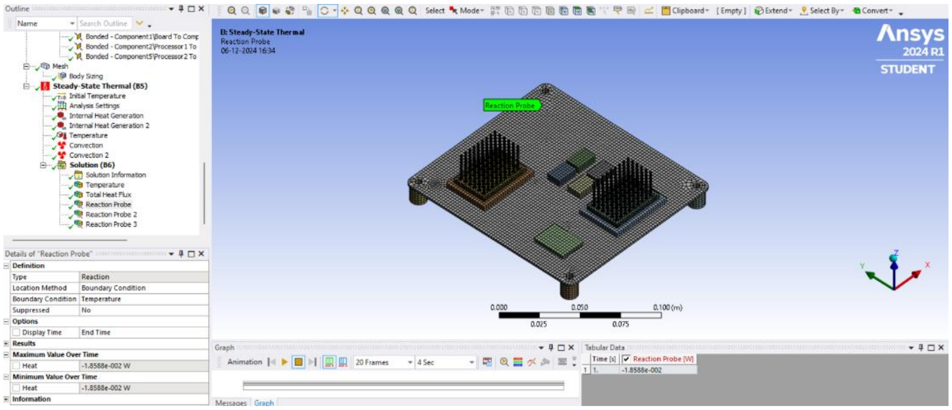
HEAT FLUX CONCENTRATION:

The heat flux is highly concentrated in the heatsink regions (highlighted in red, yellow, and green), particularly at the fins where convection dissipates heat to the surroundings.

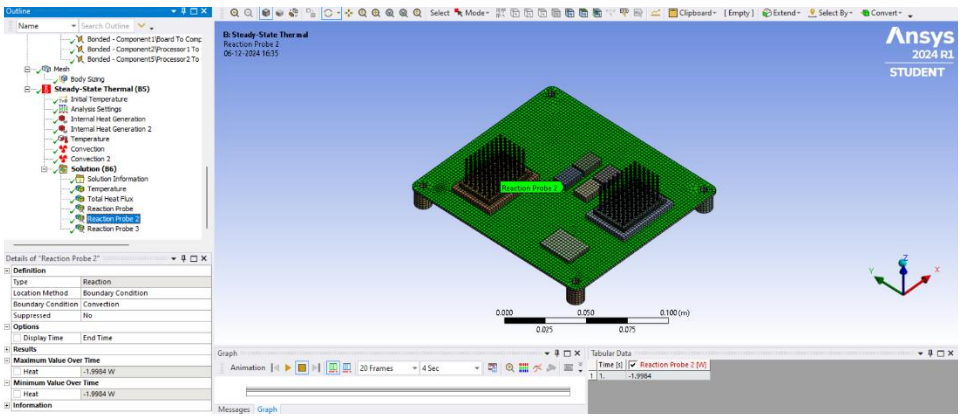
The maximum heat flux is indicated by the red arrow at one heatsink, confirming this as the critical thermal zone.



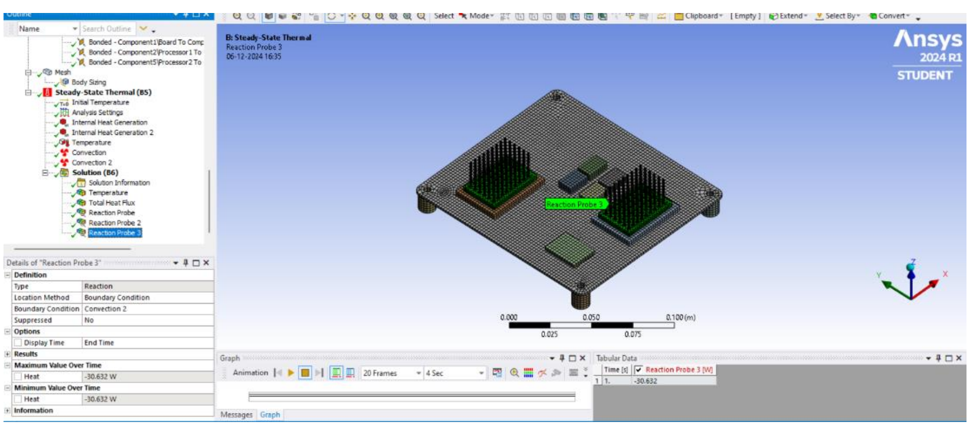
THE REACTION PROBE FOR TEMPERATURE



THE REACTION PROBE FOR NATURAL CONVECTION



THE REACTION PROBE FOR FORCED CONVECTION 2



Thermal Conductance = 5000 W/(m^2·°C), Fan = Good (h = 50 W/(m^2·°C)

Total Cost: Thermal Conductance value + fan option

= $50*2+$25

= $ 125

Total Weight: 0.4721 kg

But in this iteration I got the weight as 0.4721 kg but the given conditions the fan weight is 0.15 kg . it satisfy the given weight conditions

In this ieration we reached the temperature below the 80 C by using the good materials.

The main reason for increase in the weight because of the material used in this iteration as the copper.

I think the total cost is $65 is a reasonable cost for the customer .

Advantages:

1. **Cost-Effective:** It balances higher performance without the excessive cost of 10000 W/(m^2·°C) conductance or the Better fan.
2. **Moderate Weight:** 0.4721 kg is light enough to not significantly impact the overall system weight.
3. **Performance:** The heat transfer coefficient of 50 W/(m^2·°C) ensures effective cooling, keeping the processor's temperature well below the critical limit of 80°C.

ITERATION 3 (TYPE C)

In this iteration I used heat sink C

Material Composition:

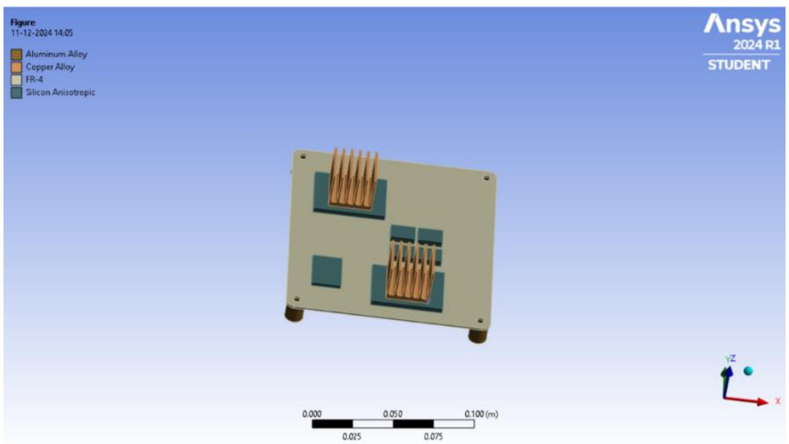
The model appears to be made up of several different materials:

Aluminum Alloy: For stands (1-4)

Copper Alloy: heat sinks 1 and heat sinks 2 heat sinks due to its excellent thermal conductivity.

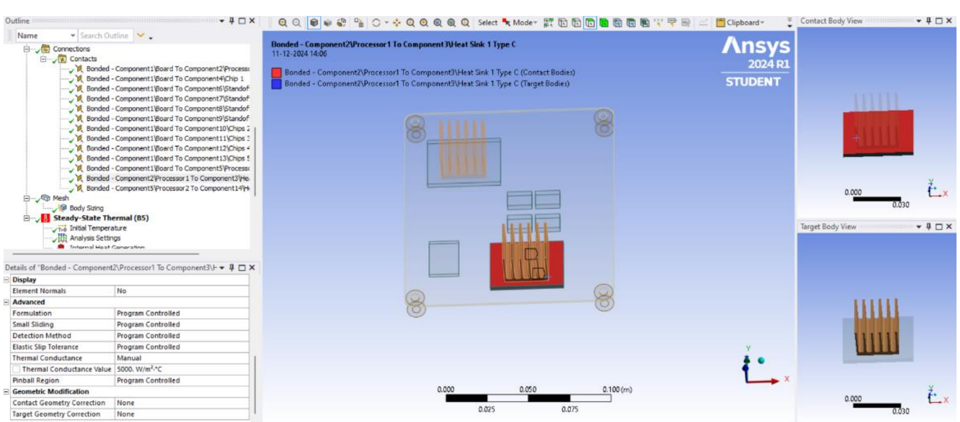
FR-4: A common material for circuit boards (PCBs).

Silicon Anisotropic: Likely used for chips, known for its semiconductor properties.

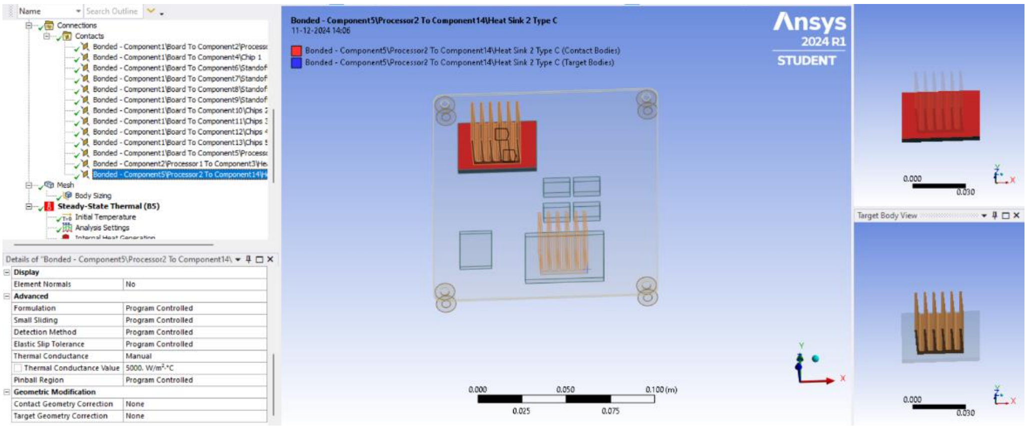


THERMAL CONDUCTANCE TO HEAT SINK 1

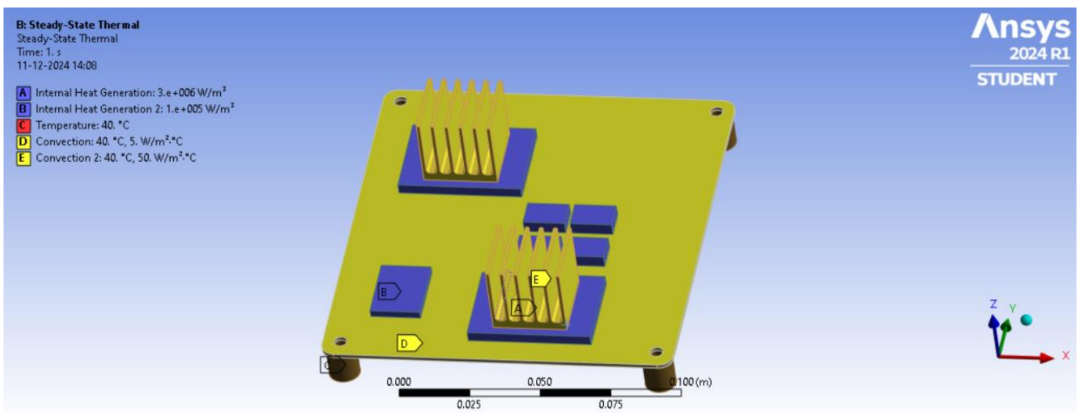
In this we used the bonded contact between the heatsink and the the conductance material . we used the thermal conductance as 5000 W/M^2 C for both the heat sinks.



THERMAL CONDUCTANCE TO HEAT SINK 1

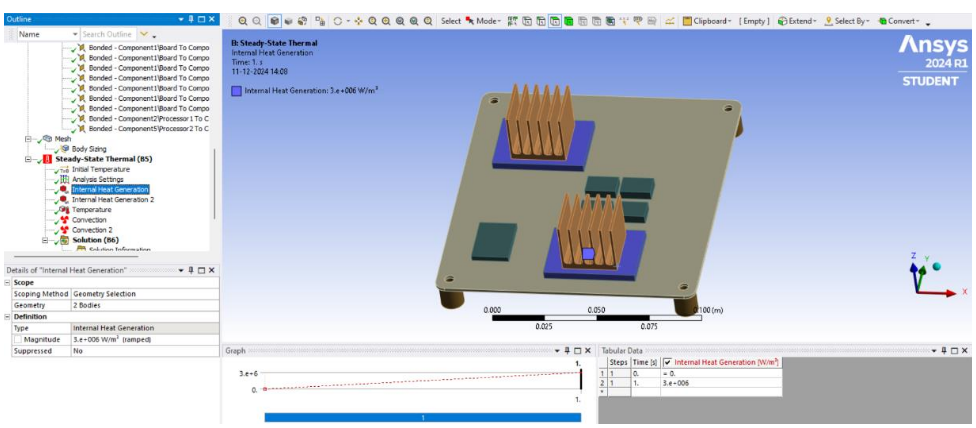


STEADY STATE CONDITION



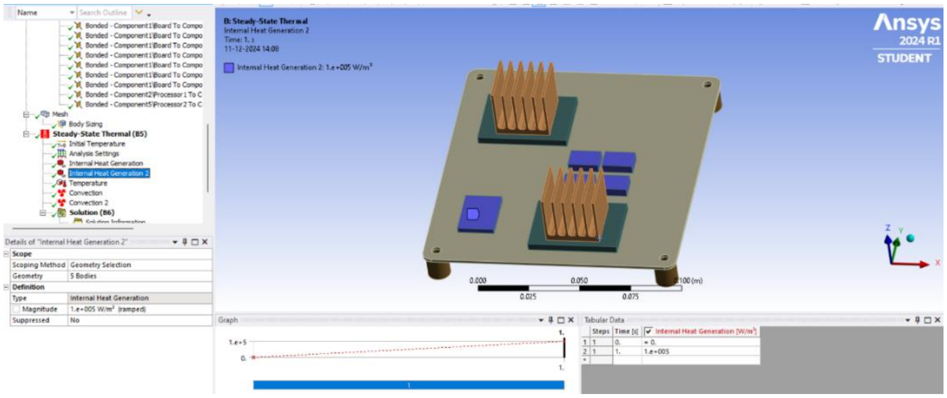
INTERNAL HEAT GENERATION

In the steady state conditions we use the internal heat generation for all the five chips as 3.e6 W/m^3.

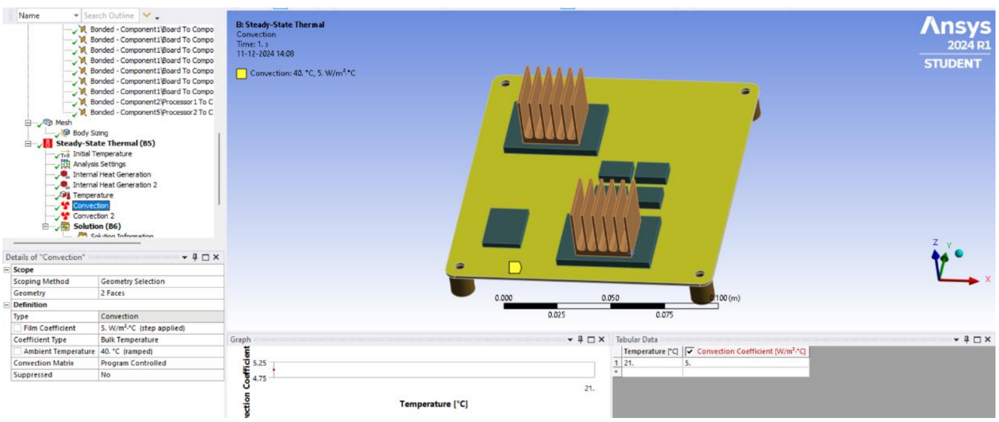


INTERNAL HEAT GENERATION 2

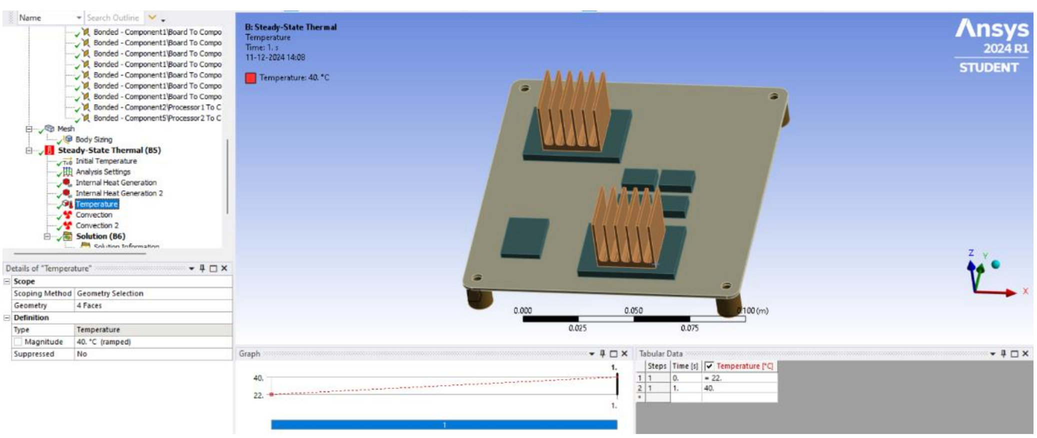
In the steady state conditions we use the internal heat generation for all the five chips as 1.0×10^5 W/m^3.



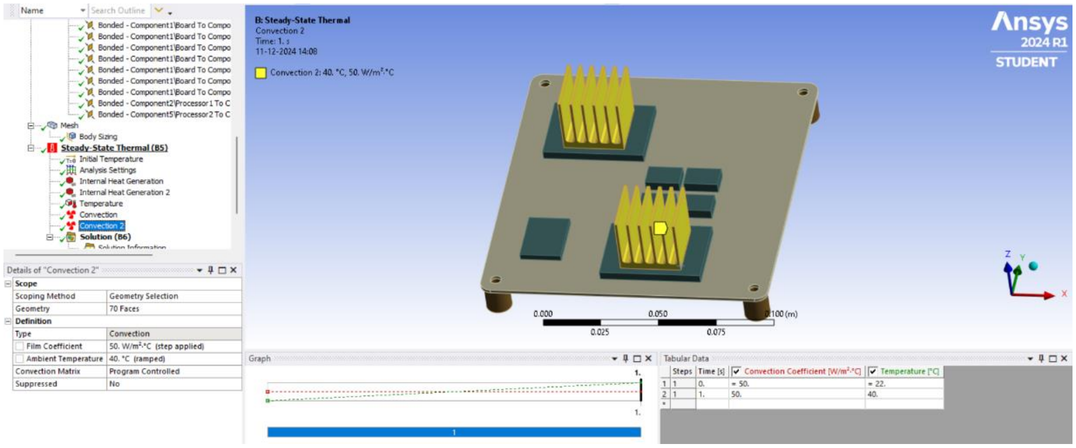
NATURAL CONVECTION



FIXED TEMPERATURE

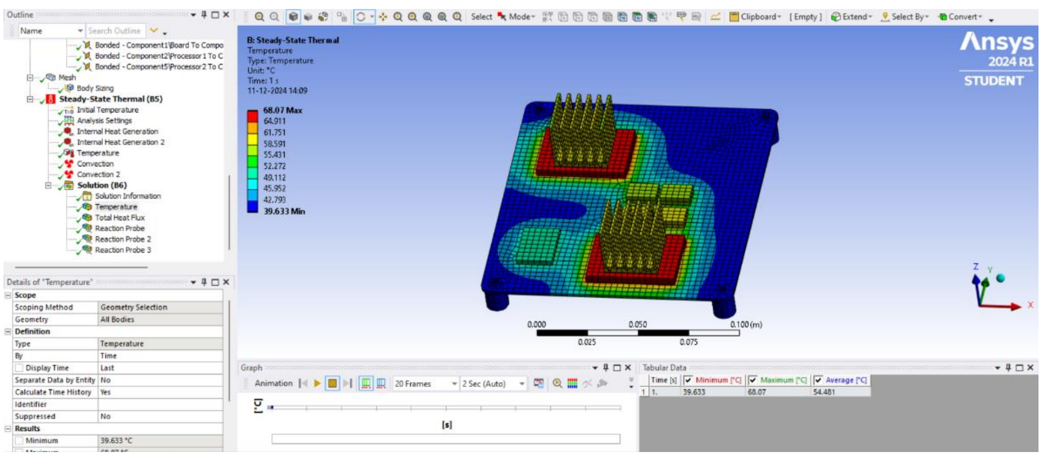


FORCED CONVECTION



TEMPERATURE:

Here the temperature is below the 80 C so it satistys the customer satisfaction. It has a temperature of 79.068 max at the processer and minimum of 39.484 C . I thnk it satisfys the given conditions .

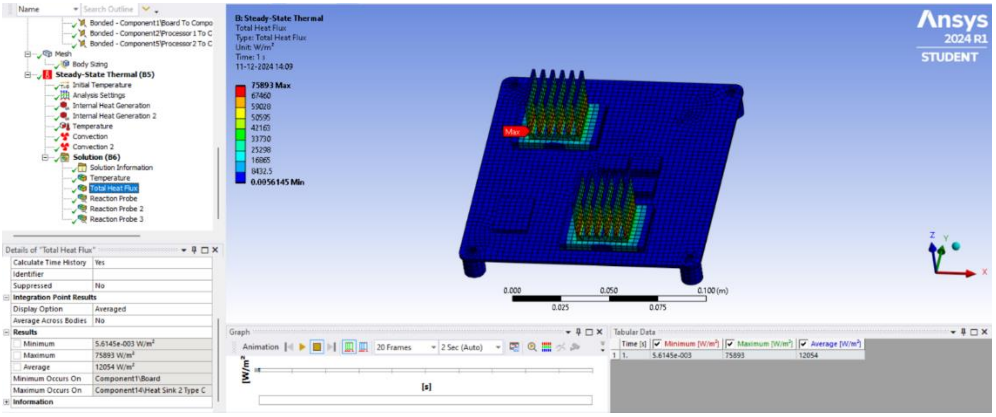


Heat Flux Concentration:

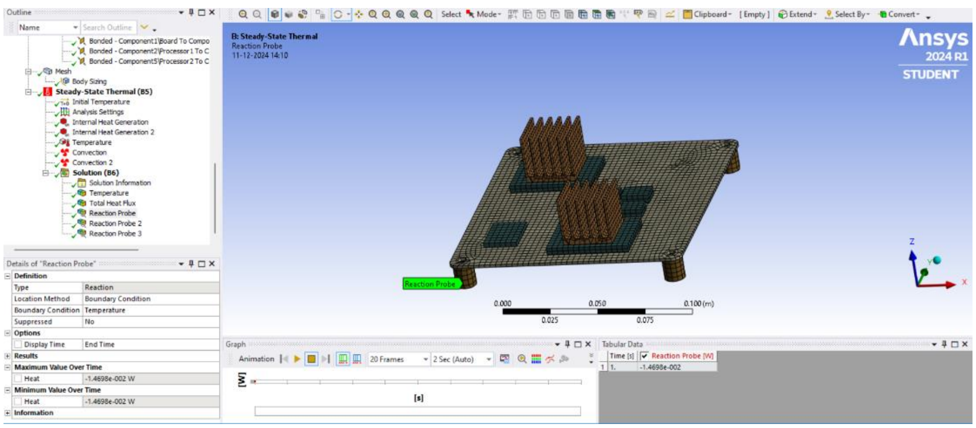
The heatsinks show a gradient of heat flux:

Higher near the base of the heatsinks, where the internal heat is concentrated.

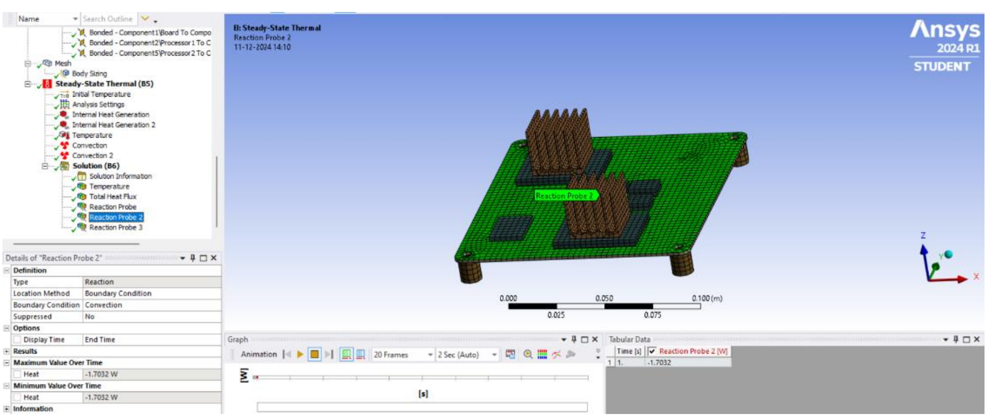
Gradually reducing towards the fins, indicating the dissipation of heat through convection.



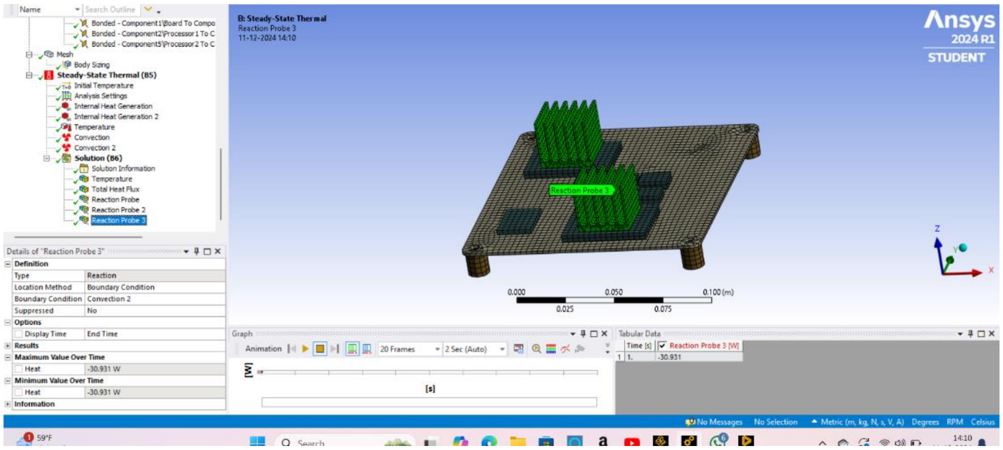
THE REACTION PROBE FOR TEMPERATURE



THE REACTION PROBE FOR NATURAL CONVECTION



THE REACTION PROBE FOR FORCED CONVECTION 2



The combination of **Thermal Conductance = 5000 W/(m^2·°C)** and **Better Fan (h = 100 W/(m^2·°C)** is a high-performance option offering robust cooling at a slightly higher cost and weight.

Thermal Conductance: 5000 W/(m^2·°C)

Fan Type: Better (h = 100 W/(m^2·°C))

Total Cost: Thermal Conductance value + fan option

= $25*2+$25

= $ 125

Total Cost: $125

But in this iteration, I got the weight as 0.5823kg but the given conditions the weight is 0.2 kg fan it satisfy the given weight conditions. In this iteration we reached the temperature below 80 C by using the good materials.

Here we used the copper alloys as heat sink materials in this iteration. I got the satisfying all the design conditions and boundary conditions and satisfying the customer requirements.

Advantages:

1. **High Efficiency:** The higher heat transfer coefficient of 100 W/(m^2·°C) ensures superior cooling performance, keeping temperatures well below 80°C even under heavy thermal loads.
2. **Moderate Cost:** While slightly more expensive, this setup provides excellent value for performance-critical applications.

3. **Improved Thermal Management:** Ideal for situations where maintaining lower operating temperatures is crucial for reliability and extended lifespan of components.

WEIGHT SUMMARY:

FOR ITERATION 1:

Weight of the board:0.2154kg

Weight of each fan= 0.15kg

Total weight of two fans: 0.15kg *2 = 0.30kg

Total weight of the PCB = weight of board + weight of fans

= 0.2154kg + 0.30kg

= 0.5154kg

FOR ITERATION 2:

Weight of the board:0.1721kg

Weight of each fan= 0.15kg

Total weight of two fans : 0.15kg *2 = 0.30kg

Total weight of the PCB = weight of board + weight of fans

= 0.1721kg + 0.30kg

= 0.4721kg

FOR ITERATION 3:

Weight of the board:0.1823kg

Weight of each fan= 0.15kg

Total weight of two fans : 0.2kg *2 = 0.40kg

Total weight of the PCB = weight of board + weight of fans

= 0.1823kg + 0.40kg

= 0.5823kg

COST SUMMARY:

Iteration 1

Thermal Conductance: 5000 $W/(m^2 \cdot °C)$

Fan: Good (h = 50 $W/(m^2 \cdot °C)$)

Thermal Conductance: $25 per each application

Total Thermal Conductance cost = $25 *2

= $ 50

Fan (Good): $25 per application

Total cost of PCB = Total Thermal Conductance cost + Fan cost

= $50 + $25

= $ 75

Iteration 2

Thermal Conductance: 10000 $W/(m^2 \cdot °C)$

Fan: Better (h = 100 $W/(m^2 \cdot °C)$)

Thermal Conductance: $50 per application

Fan (Better): $25 per application

Total Thermal Conductance cost = $50 *2

= $ 100

Total cost of PCB = Total Thermal Conductance cost + Fan cost

= $100 + $25

= $ 125

Total Cost: $125

Iteration 3

Thermal Conductance: 5000 $W/(m^2 \cdot °C)$

Fan: Better (h = 100 $W/(m^2 \cdot °C)$)

Thermal Conductance: $25 per application

Fan (Better): $25 per application

Total Thermal Conductance cost = $25 *2

= $ 50

Fan (Good): $25 per application

Total cost of PCB = Total Thermal Conductance cost + Fan cost

= $50 + $25

= $ 75

Total Cost: $75

FINAL RECOMANDATIONS:

Iteration 1 (Cheapest Weight Option)

Thermal Conductance: 5000 W/(m^2·°C)

Fan: Good (h = 50 W/(m^2·°C))

Cost of Thermal Conductance: $25 per application → $50 .

Fan: $15 per fan → $15 (1 fan).

Total Cost: $65.

Weight comparison

Weight of the board: 0.2154 kg.

Weight of two fans: 0.15 kg × 2 = 0.30 kg.

Total Weight: 0.5154 kg.

Convective heat transfer coefficient, h = 50 W/(m^2·°C), provides sufficient cooling for moderate heat dissipation.

Iteration 2 (Most Expensive Option)

Thermal Conductance: 10000 W/(m^2·°C)

Fan: Better (h = 100 W/(m^2·°C))

Cost of Thermal Conductance: $50 per application → $100.

Fan: $25 per fan → $25 (1 fan).

Total Cost: $125.

Weight comparison:

Weight of the board: 0.1721 kg.

Weight of two fans: 0.15 kg × 2 = 0.30 kg.

Total Weight: 0.4721 kg.

Higher cooling efficiency ensures better long-term reliability for high-performance systems. It provides a safety margin for higher heat dissipation

Iteration 3 (Balanced Option)

Thermal Conductance: 5000 W/(m^2·°C)

Fan: Better (h = 100 W/(m^2·°C))

Cost of Thermal Conductance: $25 per application → $50 .

Fan: $25 per fan → $25 (1 fan).

Total Cost: $75.

Weight comparison:

Weight of the board: 0.1823 kg.

Weight of two fans: 0.2 kg × 2 = 0.40 kg.

Total Weight: 0.5823 kg.

Cheapest Cost (iteration 1)

- Iteration 1 has the lowest total cost of $65.
- This configuration uses 5000 W/(m^2·°C) thermal conductance and Good Fans (h = 50 W/(m^2·°C)), which provide a balanced performance while minimizing expenses.

Lightest Weight (iteration 2)

- Iteration 2 has the lowest total weight of 0.4721 kg.
- It achieves this by using 10000 W/(m^2·°C) thermal conductance and Better Fans (h = 100 W/(m^2·°C)), although it incurs the highest cost of $125.

Recommendation

For a cost-effective and lightweight balance, Iteration 1 is the best choice:

Cost: $65 (lowest among all the iterations).

Weight: 0.5154 kg (slightly heavier than Iteration 2 but much cheaper compared to other 2).

This is ideal for systems requiring moderate cooling performance without compromising on affordability.

It balances efficiency and cost effectively, keeping the temperature below the maximum limit under normal operating conditions.

This is suitable for systems with moderate heat dissipation needs or typical environmental conditions.