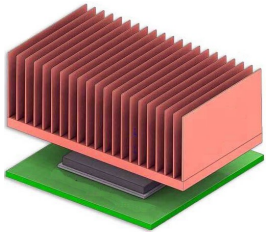
Design Optimization of CPU Heatsink/Cold Plate

Objective:

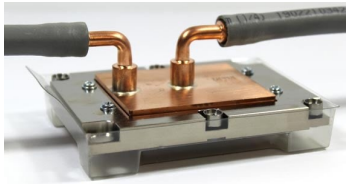
The participating student teams will design, analyse, and optimise a CPU heat sink and cold plate to minimize the maximum temperature of the base (where it contacts the CPU) by optimizing the heatsink/cold plate geometry for uniform heat source

Natural convection without the need for forced air



Forced convection with the assistance of a fan

Liquid cooling with the assistance of a cold plate



Scoring Metrics:

$$FOM = \frac{1}{\$_{hs} \cdot (T_{base} - T_{amb})}$$

$$\$_{hs} = \$_{mat} \cdot m_{hs}$$

Where T_{base} – is the maximum temperature of the heatsink base, T_{amb} – ambient temperature, $\$_{mat}$ = 80 USD/kg, m_{hs} – mass in kg of the heatsink/cold plate

Design Constraints:

- Heatsink/cold plate dimensions must stay within the specified constraints.
- Ensure manufacturability (no extremely thin fins or complex shapes that are difficult to produce).

Analysis Requirements:

- Perform a thermal analysis to calculate the heat dissipation rate.
- Perform fluid dynamics analysis to assess air movement around the heatsink / airflow patterns and pressure drop across the heatsink / airflow pattern, turbulence, and pressure drop due to impingement jets.
- Use computational fluid dynamics (CFD) simulations to optimize the cooling process.

Deliverables:

- Optimized heatsink/cold plaet design with detailed dimensions.
- A report summarizing the optimization process, including:
- Design comparison.
- Fan performance considerations (e.g., airflow rate, noise levels).
- Liquid cooling performance considerations (e.g., flow rate, pressure drop, cavitation effects).
- Temperature distribution and airflow pattern visualizations.
- Thermal performance metrics (e.g., maximum temperature, thermal resistance).
- Recommendations.

Tools:

- CAD software for model design (e.g., Freecad, OnShape).
- CFD software for thermal and fluid flow analysis (e.g., SimFlow).

Design Optimization of CPU Heatsink for Natural Convection

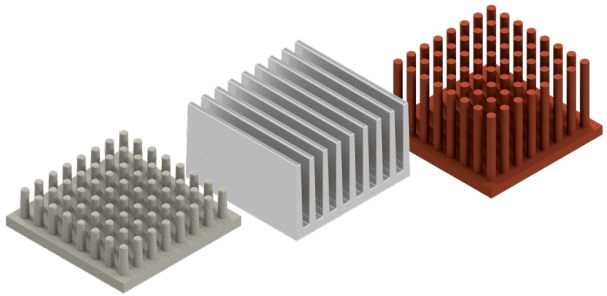
Input data:

Parameter	Value
Maximum thermal design power (TDP), W	15
Maximum operating temperature, °C	85
Ambient temperature, °C	25
Thermal conductivity of PCB, W/m·K	1.2
Thermal conductivity of die, W/m·K	120
Thermal conductivity of TIM, W/m·K	5
Thermal conductivity of HS material, W/m·K	170
Maximum heatsink size, mm	80x80x100
CPU size, mm	35x35x0.7
PCB size, mm	80x80x1.5
TIM height, mm	0.1
Base thickness, mm	5
Fin thickness, mm	1-3
Minimum fin spacing, mm	1.5

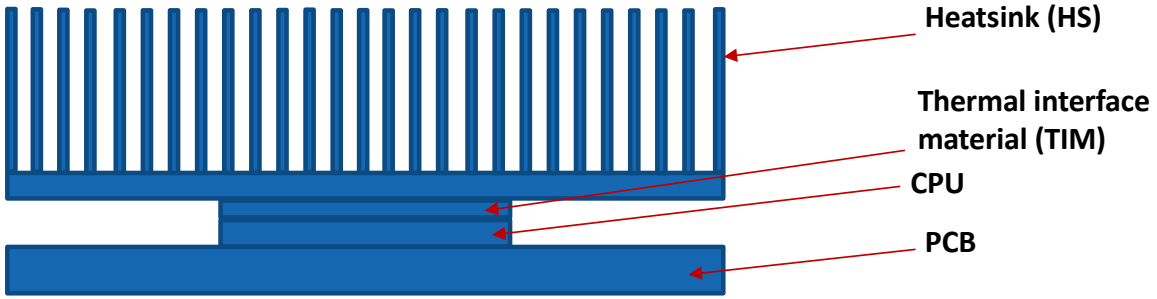
Optimization Requirements:

Optimization Parameters:
- Fin shape (rectangular, tapered, pin, etc.).
- Fin height, thickness, and spacing.

Possible designs of heatsink



Preliminary system design



Design Optimization of CPU Heatsink for Forced Convection

Input data:

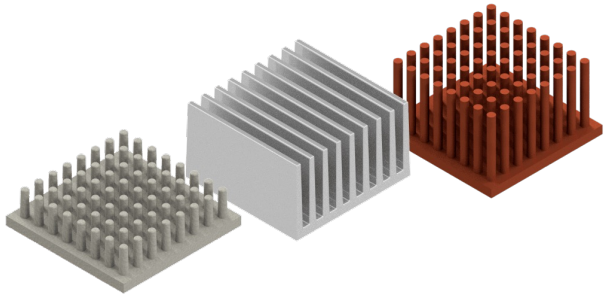
Parameter	Value
Maximum thermal design power (TDP), W	150
Maximum operating temperature, °C	85
Ambient temperature, °C	25
Thermal conductivity of PCB, W/m·K	1.2
Thermal conductivity of die, W/m·K	120
Thermal conductivity of TIM, W/m·K	5
Thermal conductivity of HS material, W/m·K	170
Maximum heatsink size, mm	80x80x100
CPU size, mm	35x35x0.7
PCB size, mm	80x80x1.5
TIM height, mm	0.1
Base thickness, mm	5
Fin thickness, mm	1-3
Minimum fin spacing, mm	1.5
Airflow speed, m/s	2
Static pressure, mm H2O	2

Optimization Requirements:

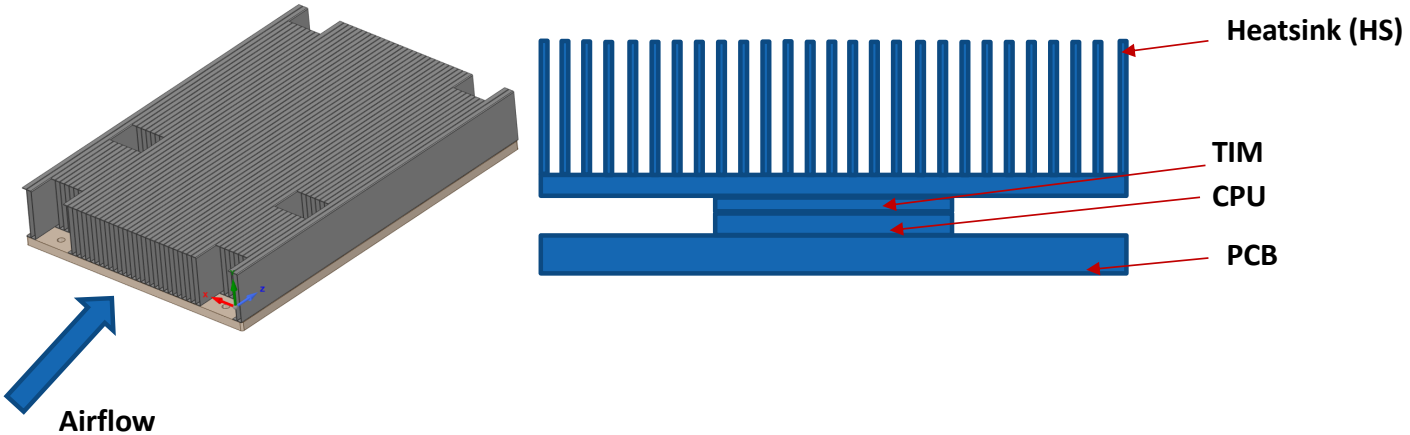
Optimization Parameters:

- Fin shape (rectangular, tapered, pin, etc.).
- Fin height, thickness, and spacing.
- Fin orientation and airflow alignment

Possible designs of heatsink



Preliminary system design

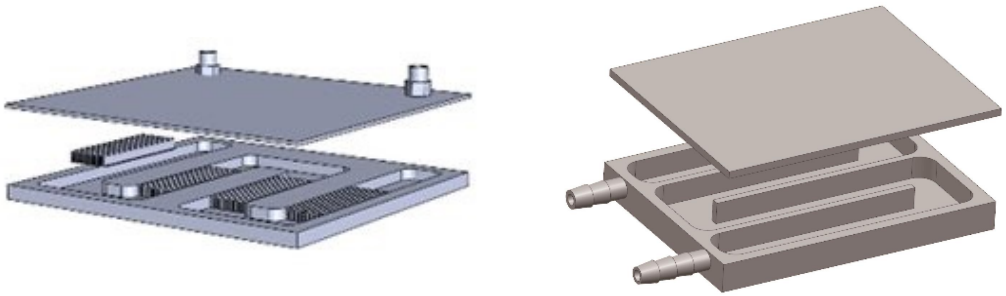


Design Optimization of CPU Heatsink for Cold Plate

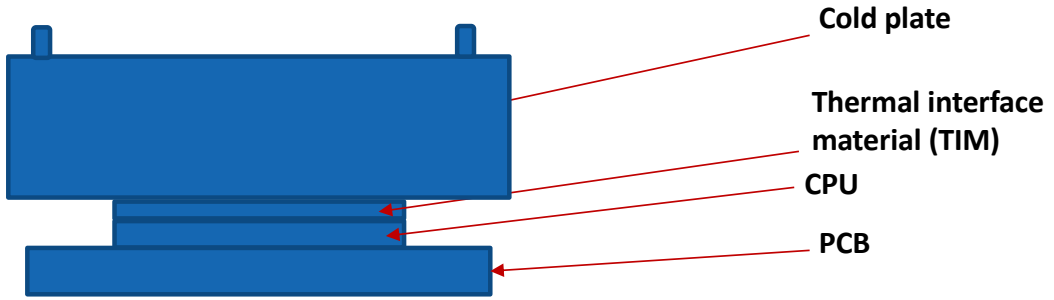
Input data:

Parameter	Value
Maximum thermal design power (TDP), W	250
Maximum operating temperature, °C	85
Ambient temperature, °C	25
Thermal conductivity of PCB, W/m·K	1.2
Thermal conductivity of die, W/m·K	120
Thermal conductivity of TIM, W/m·K	5
Thermal conductivity of cold plate material, W/m·K	170
Maximum cold plate size, mm	100x100x15
CPU size, mm	45x45x0.7
PCB size, mm	80x80x1.5
TIM height, mm	0.1
Base thickness, mm	3
Channel width, mm	0.5-3
Minimum channel spacing, mm	1
Liquid type	Water
Flow rate, l/min	2
Inlet temperature, °C	25
Pressure drop, bar	0.5

Possible designs of cold plate



Preliminary system design



Optimization Requirements:

Optimization Parameters:

- Channel shape (rectangular, circular, trapezoidal, etc.).
- Channel height, width, and spacing.
- Inlet and outlet port placement and size.
- Flow pattern (parallel, serpentine, pin-fin, etc.).