Thermal Management of CPUs

Introduction:

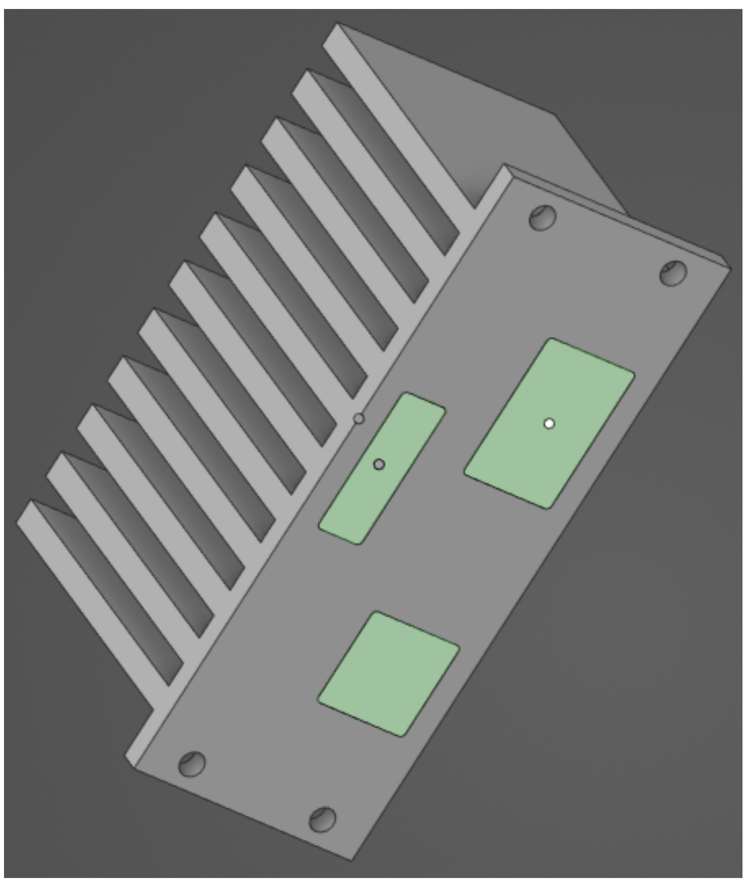
We aim to analyze the thermal behavior of CPUs and assess the impact of heat sinks on their temperature regulation.

Assumptions:

In all the analyses discussed in this document, we assume steady-state thermal conditions and consider radiative heat transfer to be negligible. Furthermore, we assume that the thermal properties remain constant throughout the process, and the conductive heat transfer is treated as linear.

Geometry:

The following figure illustrates the geometry of CPUs and the heat sink:



Material Data:

For CPUs: Silicon (from Ansys Discovery library) is utilized.

For the heat sink: Copper (from Ansys Discovery library) is employed.

Boundary Conditions:

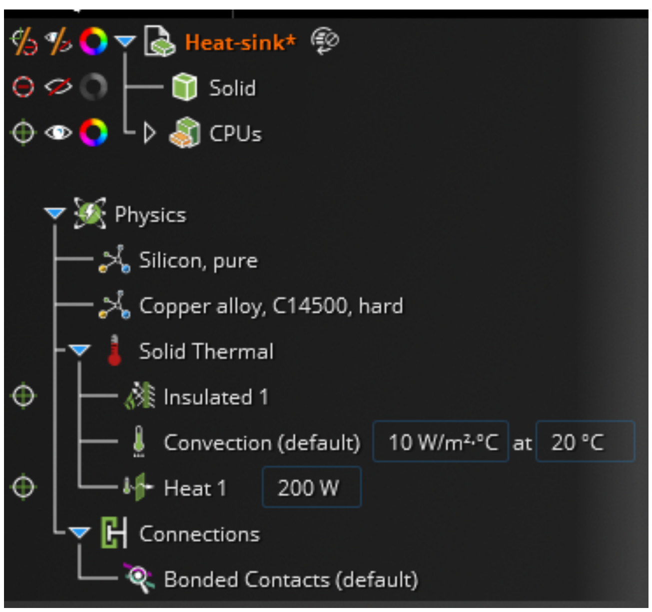
First, we conduct a thermal analysis focusing solely on the CPUs. The boundary conditions are set as follows:

200 W of heat among the 3 CPUs is applied proportional to their volume.

The bottom face of the CPUs is insulated.

A convection coefficient of 10 W/m²°C is assumed for heat transfer between the CPU surfaces and air at 20°C.

The following figure outlines the boundary conditions:



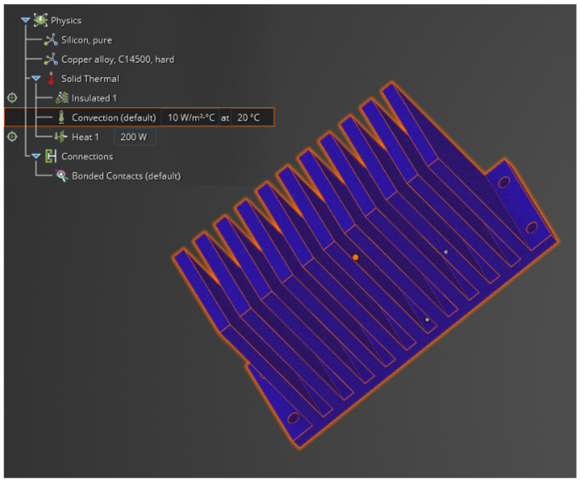
Then, heat sink is included in the analysis, and below boundary conditions are used.

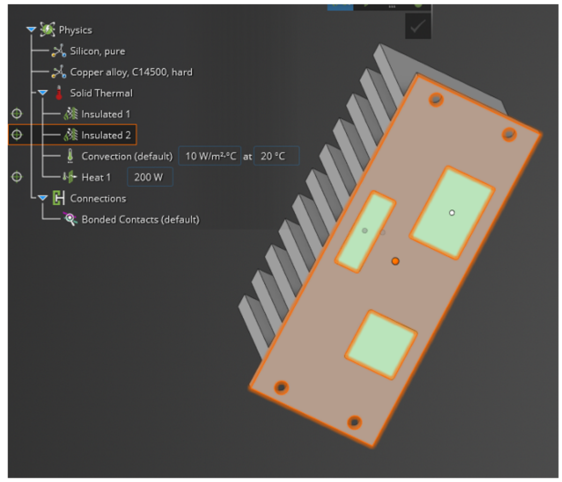
200 W of heat among the 3 CPUs is applied proportional to their volume.

The entire bottom face of the CPUs and heat sink is insulated.

A convection coefficient of 10 W/m²°C is assumed for heat transfer between the entire assembly and air at 20°C. Below plots show the surface insulation and heat convection areas:

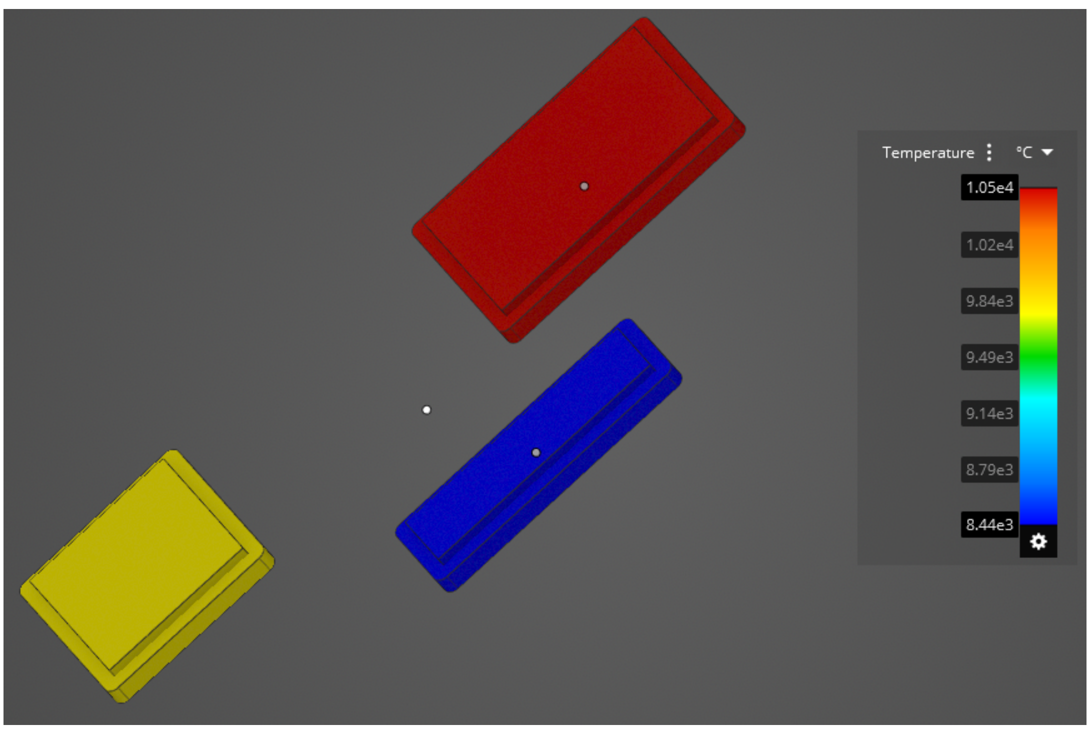
Heat convection areas	Heat insulations at the bottom





Initial Simulation Results (Without Heat Sink):

Initially, we exclude the heat sink from the simulation, analyzing only the CPUs. Below figure shows the results for that:

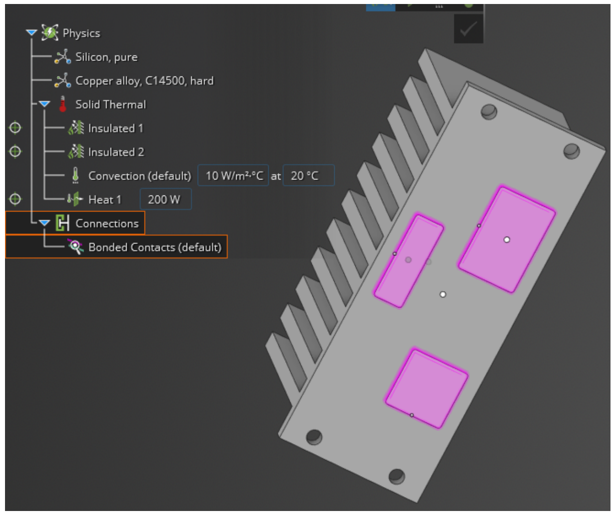


The results indicate varying temperatures across the chips, with values exceedingly high. This underscores the critical role of heat sinks in CPU temperature management.

Inclusion of Heat Sink:

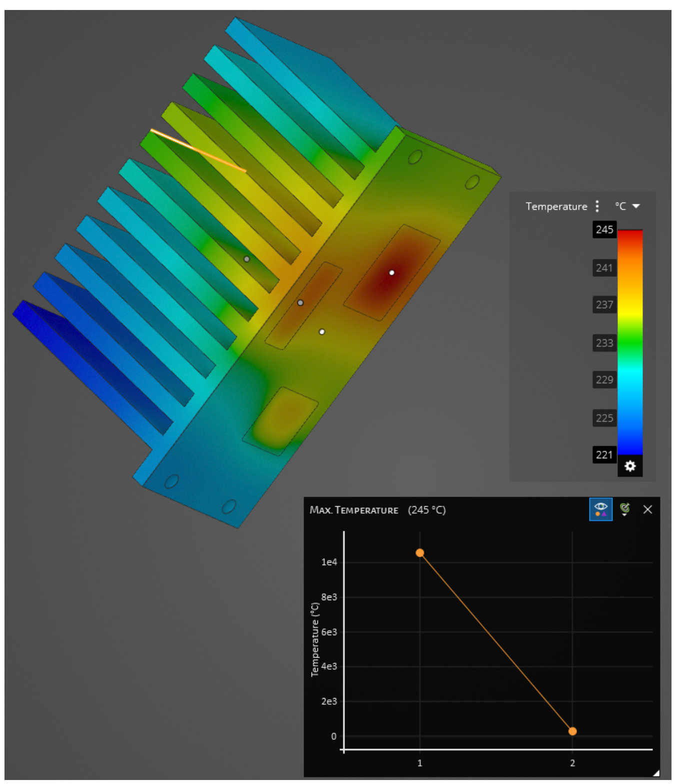
Subsequently, we integrate the heat sink into the simulation, applying heat convection across the entire assembly.

The simulation now includes connections in the physics tree (shown in below figure), representing heat conduction between the CPUs and the heat sink.



Comparative Analysis:

A comparative analysis reveals a significant temperature reduction from 1.e4 °C to 246 °C upon incorporating the heat sink.

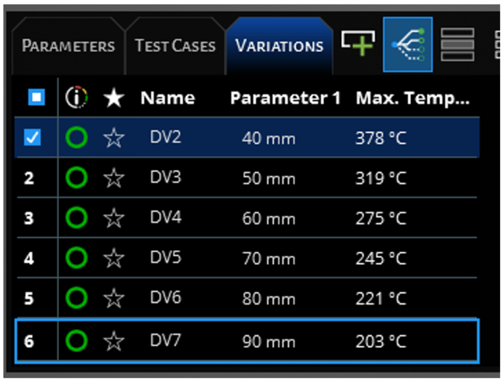


We can see that the temperature distribution is non-uniform across the chips due to the varying amounts of heat each chip generates, as well as their distinct shapes and positions.

Design Variation Analysis:

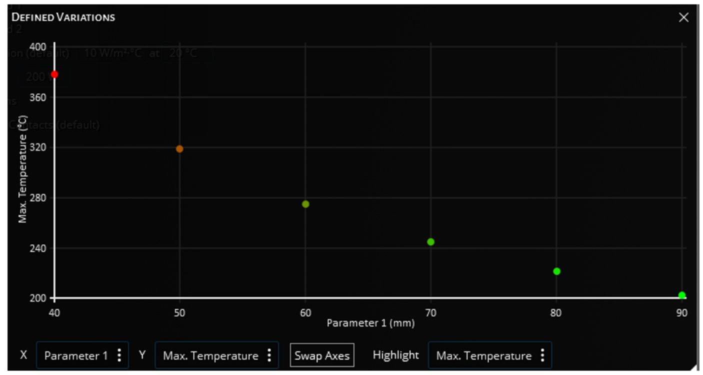
Now, we explore the impact of varying heat sink heights on the maximum temperature, ranging from 0.04 m to 0.09 m, as shown below:

Different heat sink heights and the corresponding maximum temperature



	Name	Parameter 1	Max. Temp...
1	DV2	40 mm	378 °C
2	DV3	50 mm	319 °C
3	DV4	60 mm	275 °C
4	DV5	70 mm	245 °C
5	DV6	80 mm	221 °C
6	DV7	90 mm	203 °C

Plot of maximum temperature vs heat sink height



The results demonstrate a decrease in temperature with increasing heat sink height, attributed to enhanced heat absorption and dissipation.

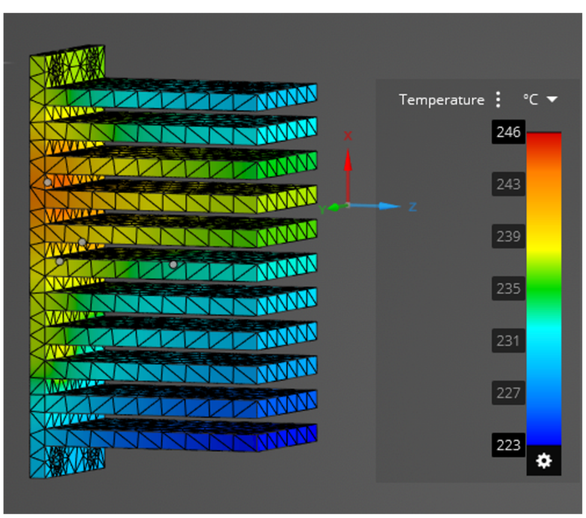
Selection of Heat Sink Height:

Based on the maximum allowable temperature, a heat sink height of 70 mm is selected for further high-fidelity analysis.

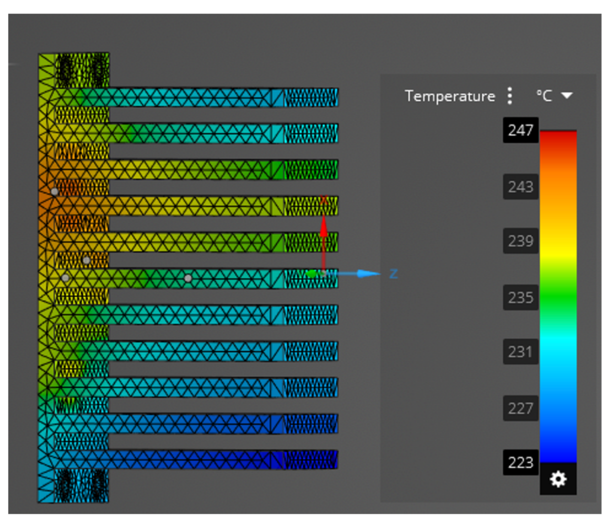
High Fidelity Analysis:

Below results show the maximum temperature of CPUs using the default mesh and a finer mesh:

Temperature results for the default mesh size



Temperature results for a finer mesh size



We see that temperature difference for finer mesh is very little compared to the default mesh size as well as previous calculations in the discovery GPU solver. As can be seen in all the calculations, the maximum temperature of the CPUs reaches above 200 C.

Final notes:

While the heat sink significantly reduces the CPU temperature, additional cooling measures, such as forced convection with a computer fan, are recommended for optimal thermal management.