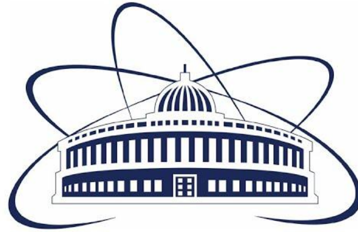

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INTEREST Internship Report

Heat Transfer Simulation of the cooling system for the NICA-MPD-Platform RACK cabinet

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Abstract

Simulations of equipment of a NICA-MPD rack cabinet were performed in order to assess the heat transfer properties of the design. A Simple 3D model was prepared and heat transfer simulations were performed on them to better understand the cooling curve, and the various thermal properties of the materials used. This report mainly discusses a heat transfer simulation performed on a PCB unit along with the designing of a simple CAD replica of the RACK cabinet of the NICA-MPD-PLATFORM to further perform a heat transfer simulation of the new liquid-air version cooling systems.

Introduction

1. NICA-MPD-Platform

NICA stands for (Nuclotron-based Ion Collider fAcility) which is built at Joint Institute for Nuclear Research (JINR) to study the properties of dense baryonic matter which will help the scientists to study more and understand the QuarkGluon Plasma state on which our Universe stayed shortly after the Big-Bang.

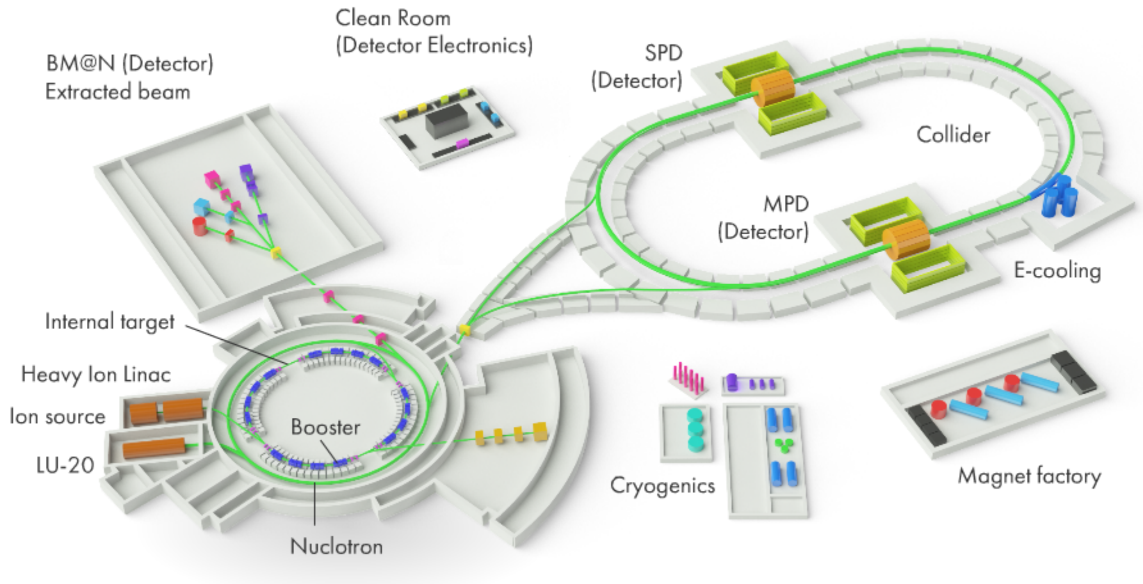


Fig1: The Nuclotron-based Ion Collider fAcility

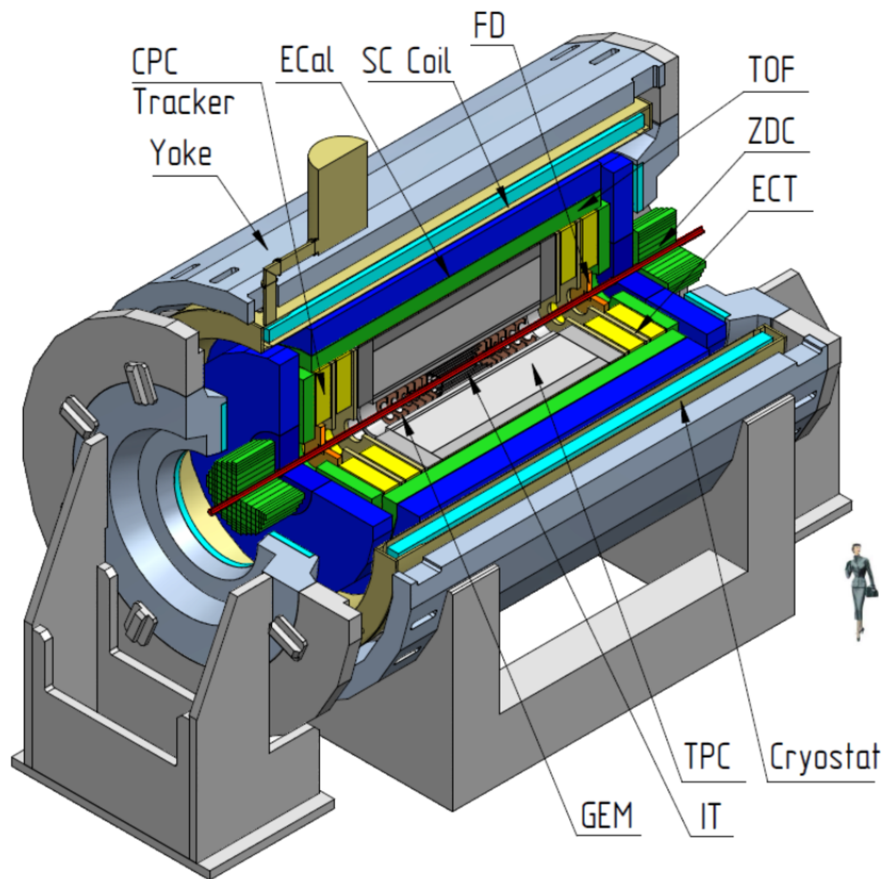


Fig2: The Multipurpose Detector

The Multipurpose Detector (NICA-MPD) platform's RACK cabinet is a structure housing highly sensitive electronic equipment whose main function is to analyse and interpret the data recorded by the particle accelerator.

2. Liquid-Air Cooling

For the proper functioning of the RACK cabinets it is very important to ensure proper conditions in order to achieve reliability of the whole system. Thus, in order to achieve its particularly high threshold of performance the cooling system of the RACK cabinet is of liquid-air combination.

Two rack cabinets are cooled down by a separate air conditioning unit placed between them in a closed loop setup.

This design of cooling prevents outside particles from getting inside the cabinet and protects the electronic equipment from the risk of contamination.
This solution ensures high purity of cooling air and improves service while lowers the operating costs.

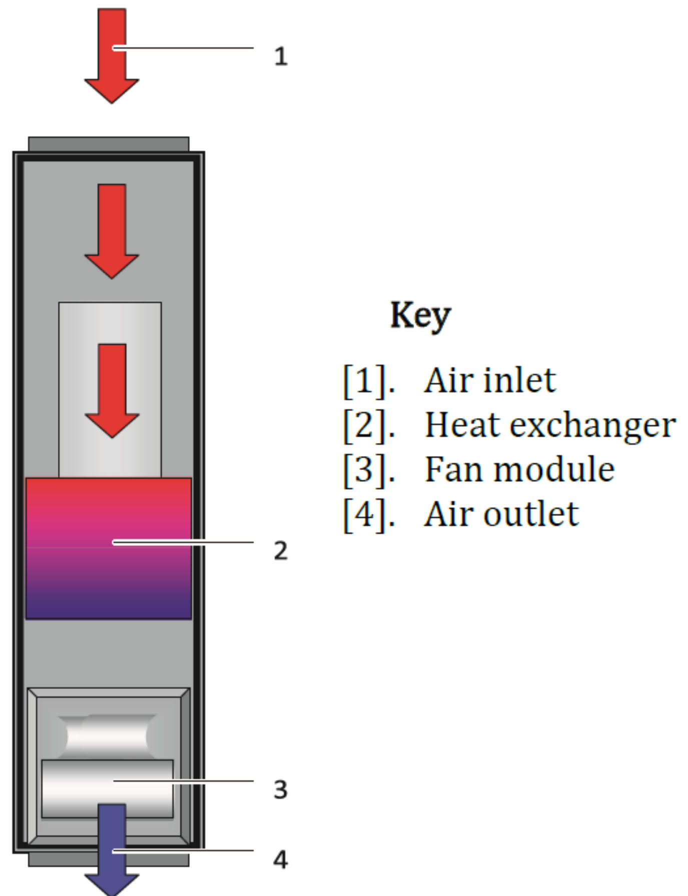


Fig3: Air-Routing(top view)

Heat Transfer Simulation

A Heat Transfer simulation of a PCB unit was performed to study the temperature outputs of the electrical unit during its normal functioning.

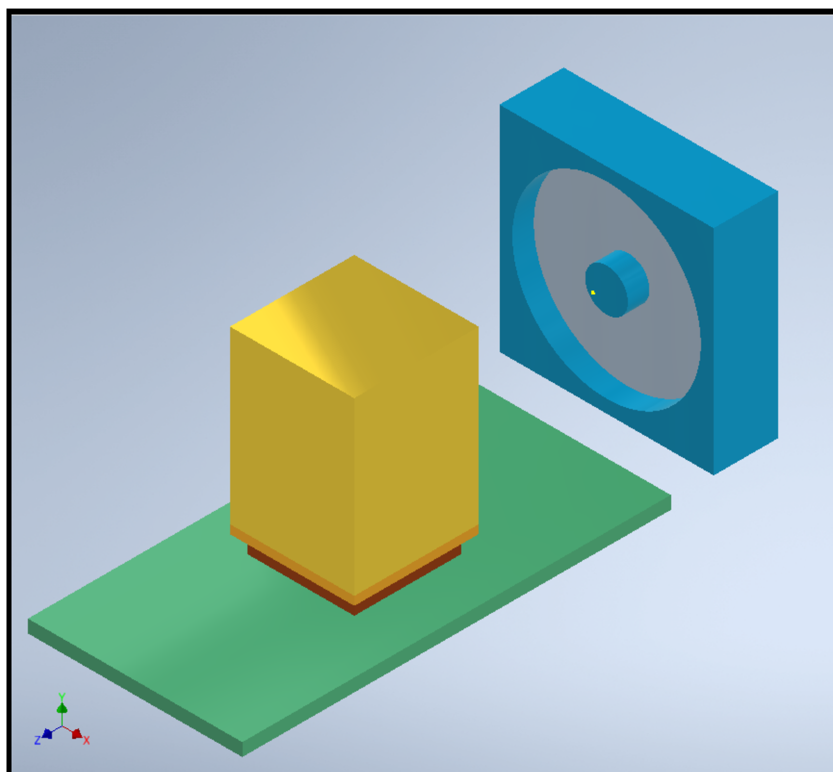
PCB unit contents:

1. PCB with a Silicon Chip having a power output of 40W
2. MC20 Heatsink
3. ComairRotron Fan

Method of Action

- A CAD model was first prepared using the Autodesk Inventor Professional 2021 software using the technical documents (Appendix A). The model structure was simplified and the minor details that were not important for the simulation were omitted.
- Using Autodesk CFD 2021, the heat transfer simulations were conducted.
    1. First, the 3D model was placed in a volume of air variable parameters.
    2. Then the material properties were assigned to each component of the PCB unit. Default materials were assigned to air and solid parts of the model.
    3. Specific parameters for default materials of the heat sink and the cooling fan were modified.
    4. In the next step the model was meshed with auto-sized parameters.
    5. Boundary conditions were set to simulate ambient conditions of operation. The outside temperature was set to be 20°C.
    6. The simulation was then solved with account for gravitation and radiation.

CAD Model
Prepared using Autodesk Inventor Pro



CFD Analysis

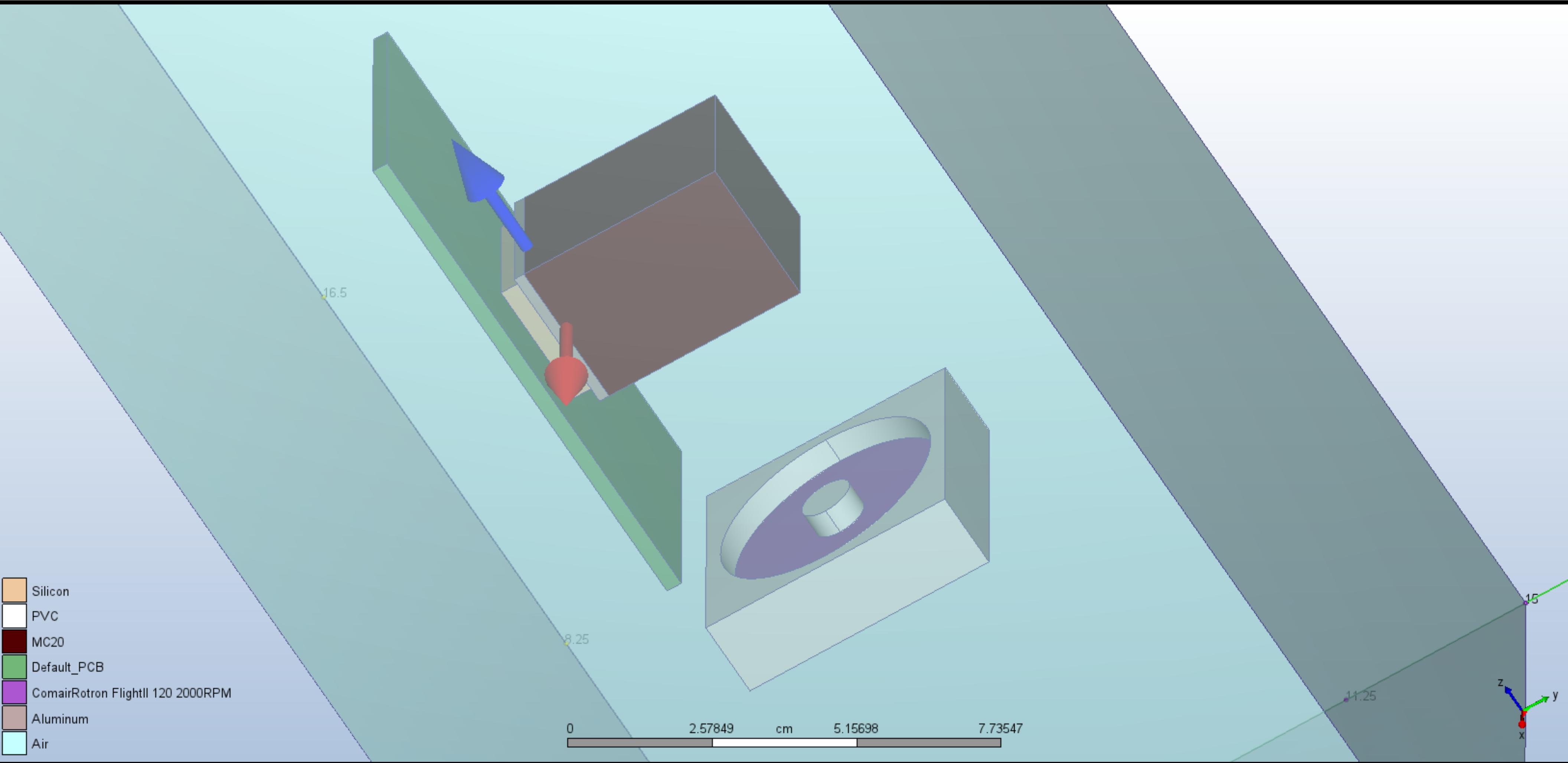


Fig5: Design to be simulated with materials assigned, in cartesian 3D

Length Units: centimeter (cm)

Materials

COMPONENT	*MATERIAL ASSIGNED*
1. Control Volume	Air.
2. ComairRotron cooling Fan	The fan’s case and hub are assigned as PVC, whereas the fan blades are assigned default Internal cooling fan material with a rotating speed of 2000 RPM in Z-direction (0,0,1).
3. MC20 Heat Sink	Default Heat sink material with; Approach surface = 16 and Base surface = 8.
4. Heat sink Base	Aluminium.
5. Chip	Silicon.
6. PCB	Default Printed Circuit Board material.

Table 1

Boundary Conditions

Condition	*Assigned To*
1. Total Heat Generation	A steady state heat generation of 40 W was assigned for the chip
2. Pressure	A pressure of 0 Pa (P= 0 Pa) was assigned to the front and back sides of the Control volume.
3. Temperature	A temperature of 20°C (T= 20 °C) was assigned to the other four lateral sides of the Control volume.

Table 2

Meshing

Automatic meshing was applied to the entire design to facilitate the simulation.
The meshed model has 14931 nodes and 70892 elements with a resolution factor of 1

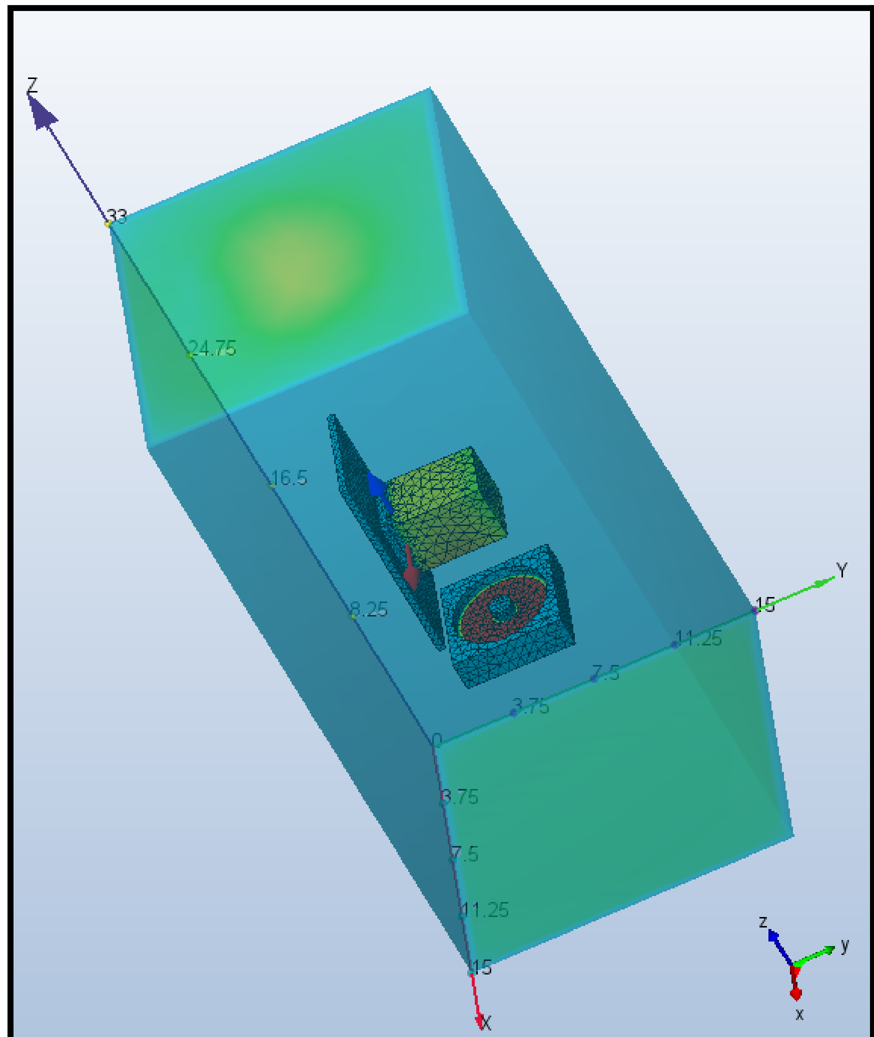


Fig6: Meshed Model

- The model after meshing was subjected to Steady State simulation of 500 iterations under the influence of gravity and radiation.
- The Gravity vector was taken along the negative Y-axis (0,-1,0).
- The active turbulence mode was k-epsilon.

Simulation Results and Inferences

1. Heat Maps

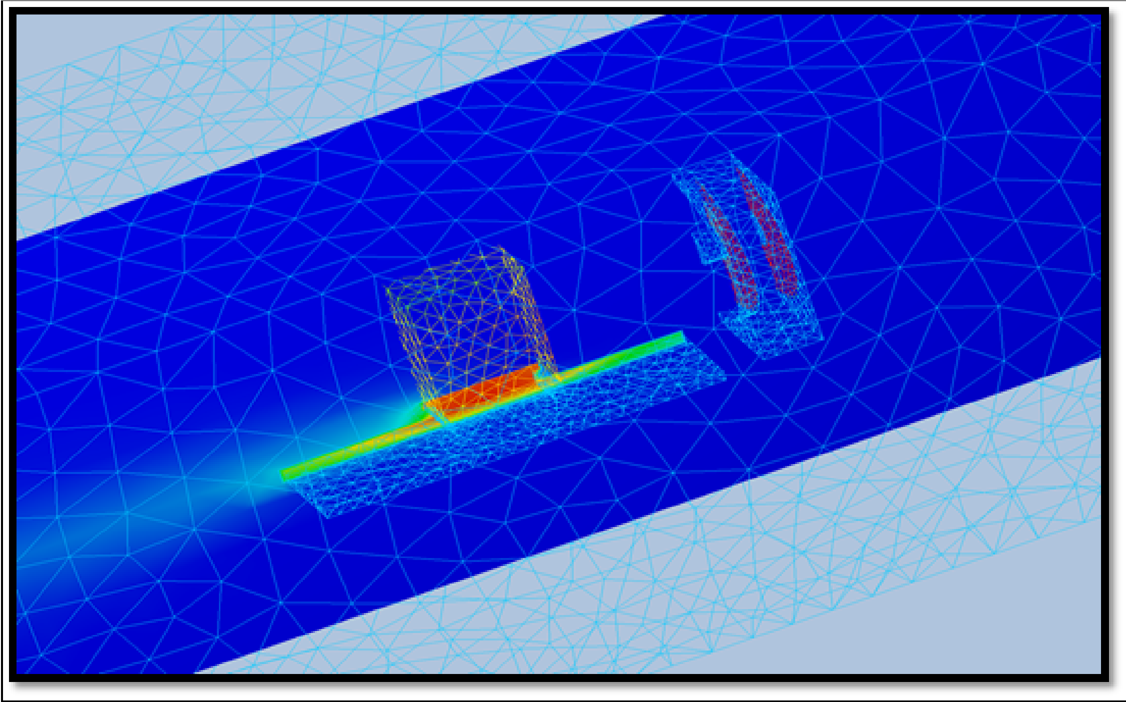


Fig7: Temperature Magnitude Diagram showing the heat dissipation from the chip under the influence of the cooling vector.

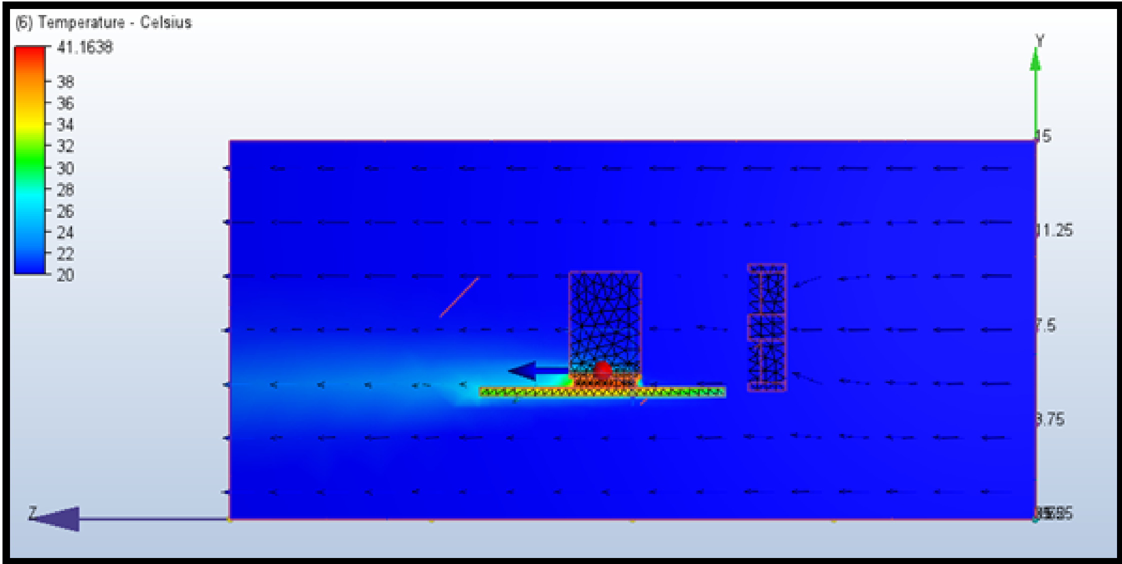
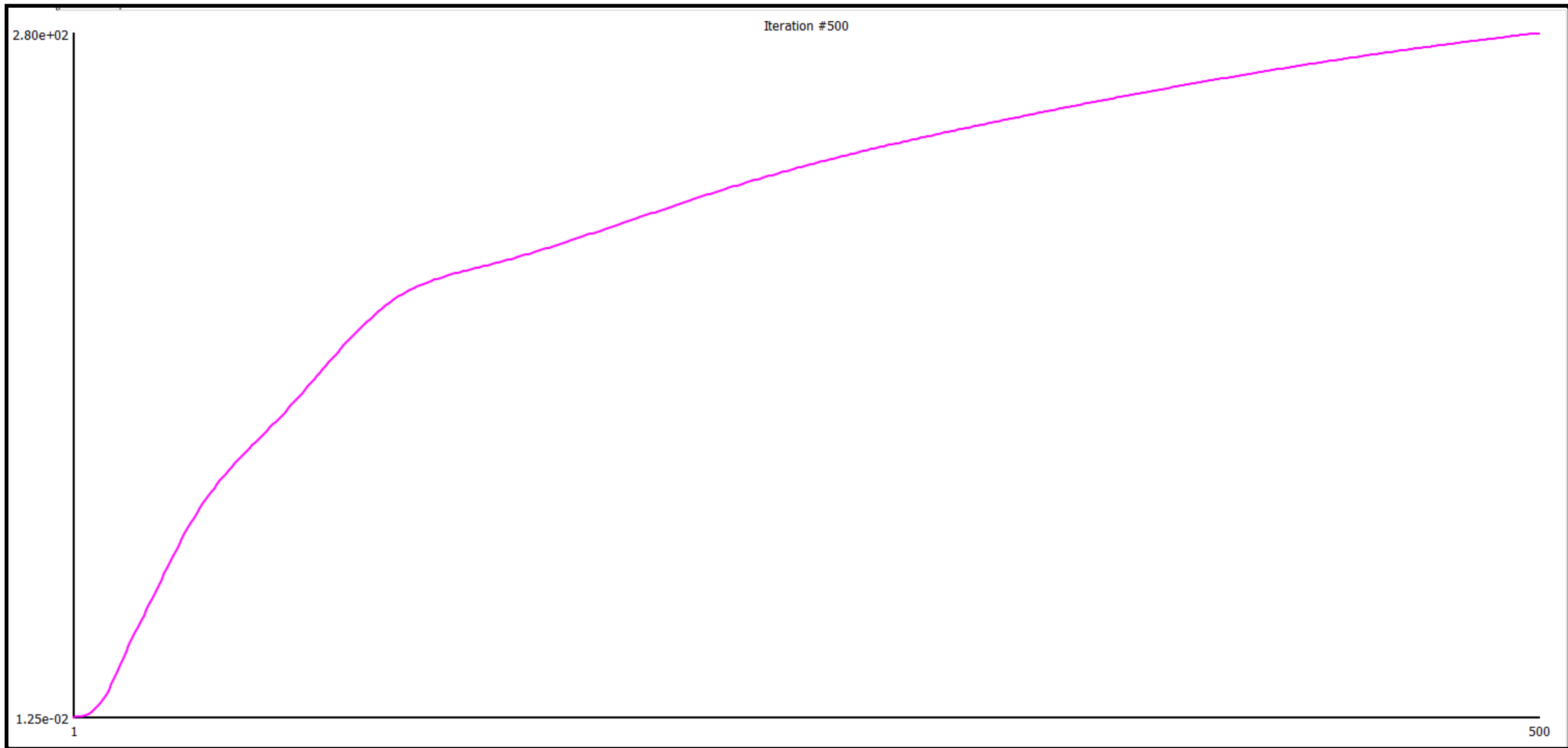
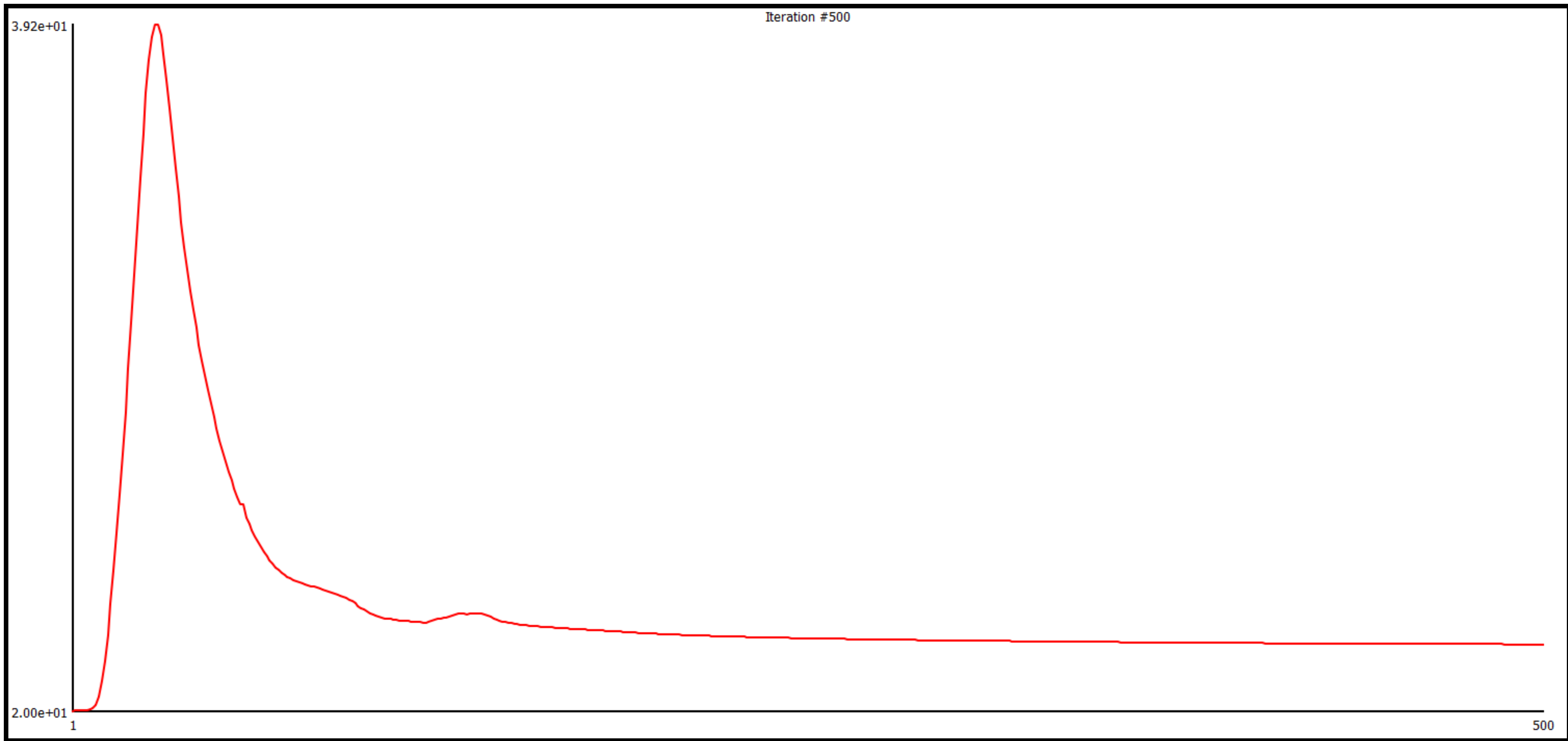


Fig8: Temperature Magnitude Diagram showing different temperature profiles along with the velocity vector.

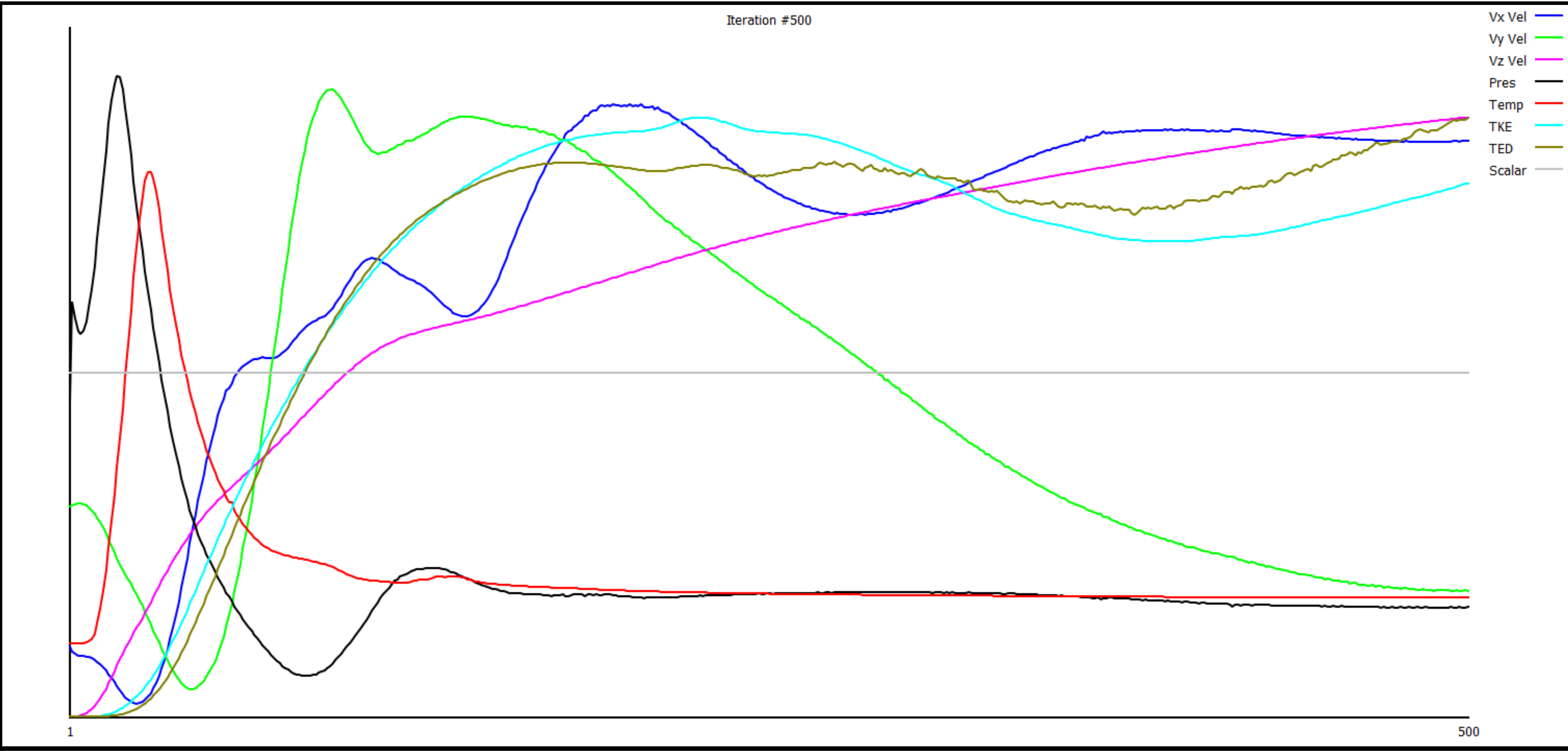
2. Convergence Plots



Plot 1: Velocity along the Z-axis (Vz)



Plot 2: Temperature plot for each iteration.



Plot 3: Convergence plots for all measured variables in the heat transfer simulation.

3. Conclusion

- From the heat maps in figure 8 and 9 the temperature effect on the PCB module is clearly evident. There is a gradient in temperature which correlates with the colour bar. In the given heat maps, we can see a higher temperature value on the Chip and the PCB since they are sources for heat generation, also in the front of the heat sink in figure 8 there is no increase in temperature since this area is well ventilated and cooled by the fan, while we can see a relative increase in the temperature on the other side of the heat sink. Additionally, similar behaviour can be noticed on the PCB, where the side facing the fan has a relative lower temperature than the other side which is a bit far from the fan behind the heat sink.
- Additional inference which can be made from the resulting heat maps of the simulation is the path of dissipation of heat from the respective heat sources (PCB and Chip) into the surrounding air medium. We observe that there is no significant rise in the temperature of the surrounding medium suggesting that the PCB unit is undergoing an effective cooling cycle.
- From convergence plot 2, convergence plot of the temperature, shows a high error value in the beginning and after a while when the temperature starts to dissipate the errors starts to decrease gradually and the convergence increases to a higher value by the end of the 500th iteration.
- From convergence plot 1, convergence plot of velocity along the Z-axis, starts off from a small value and reaches a higher value indicating the increase in velocity along the z-axis, possibly signalling the increase in the speed of the cooling fan which leads to an increase in the velocity along the z-axis.
- During the simulation the Silicon Chip recorded a maximum temperature value of 40.4987 °C, a minimum temperature of 37.8915 °C and an average temperature reading of 39.7016 °C, clearly indicating an effective cycle of cooling. Similarly the surrounding air volume recorded a maximum temperature of 41.1638 °C and a minimum temperature of 20 °C while its average temperature was recorded at 20.0941 °C. This again strengthens our initial inference that the cooling cycle of the PCB unit is effective.

CAD Model of the RACK Cabinet

The RACK Cabinet as mentioned in the report introduction is a structure housing highly sensitive electronic equipment whose main function is to analyse and interpret the data recorded by the particle accelerator.
For designing the CAD model of the same, the main components I made use of are:

1. 19” Rack.
2. Easy 3000 crate for powering support.
3. NIM8304 fan unit.
4. 2U Server fan.

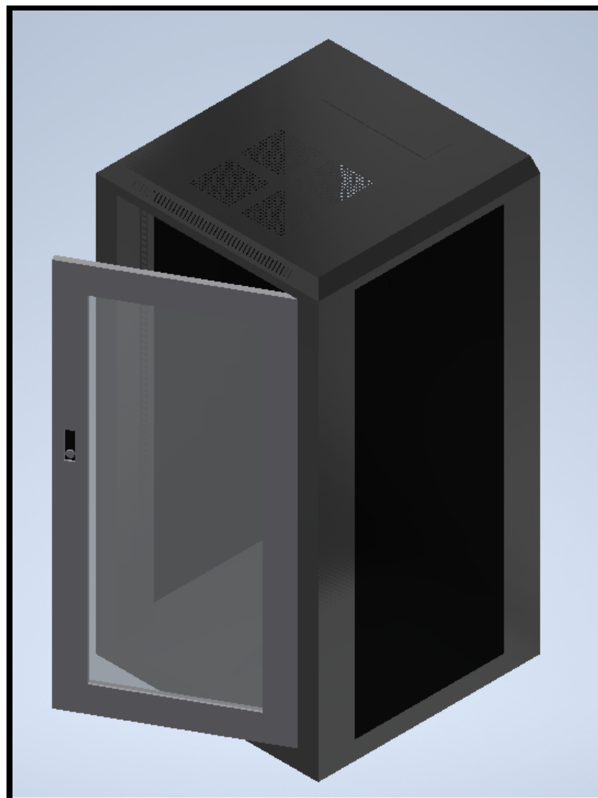
Method of Action

- Design the CAD models of each part or component individually using the Autodesk Inventor Pro software.
- Integrate and assemble all of them together to form the final simplified replica of the RACK cabinet.

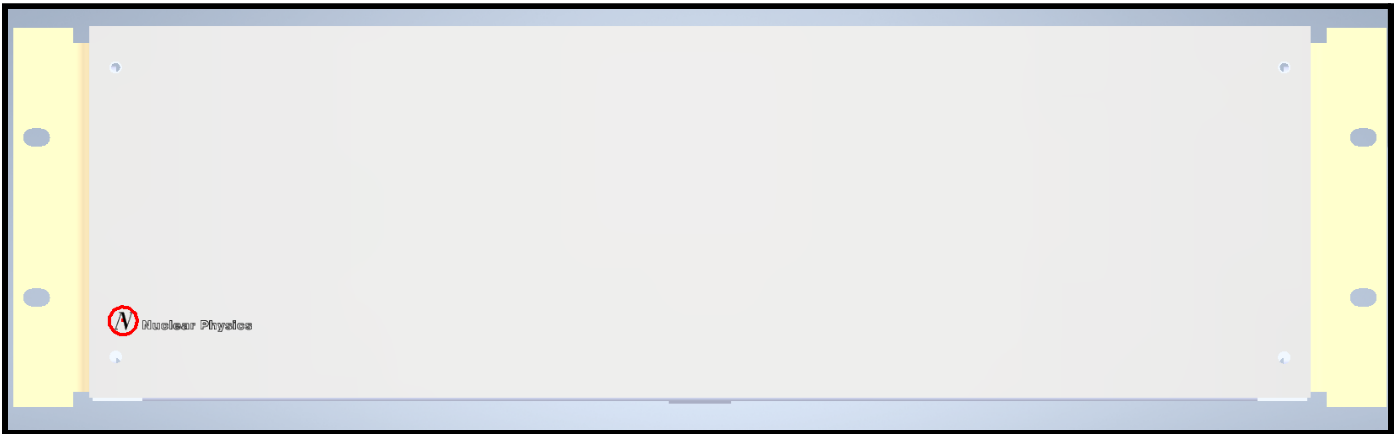
Component Model

1. **19” Rack.**

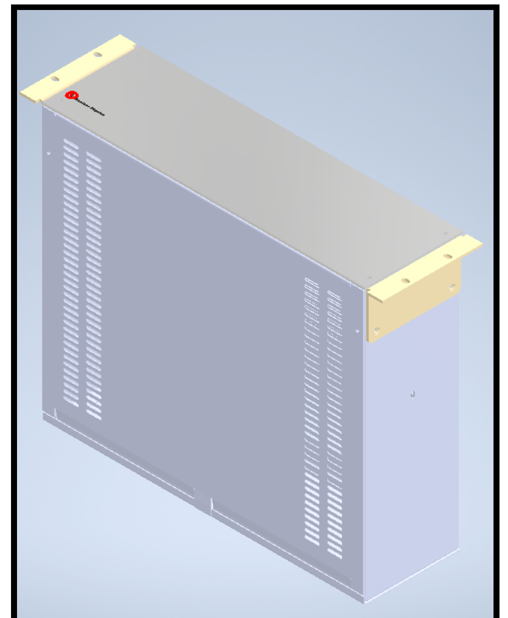
   The 19 inch rack cabinet is mainly used to house all the other sensitive electronic components.
   It does not have a power supply or a cooling system of its own, hence we need to provide it with a separate cooling system in order to ensure the proper functioning of the components housed within it.

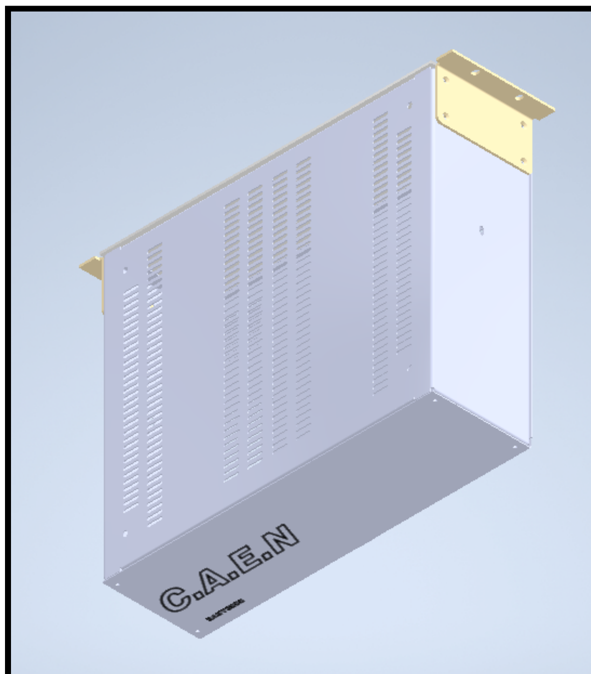


2. C.A.E.N Easy 3000 Crate.



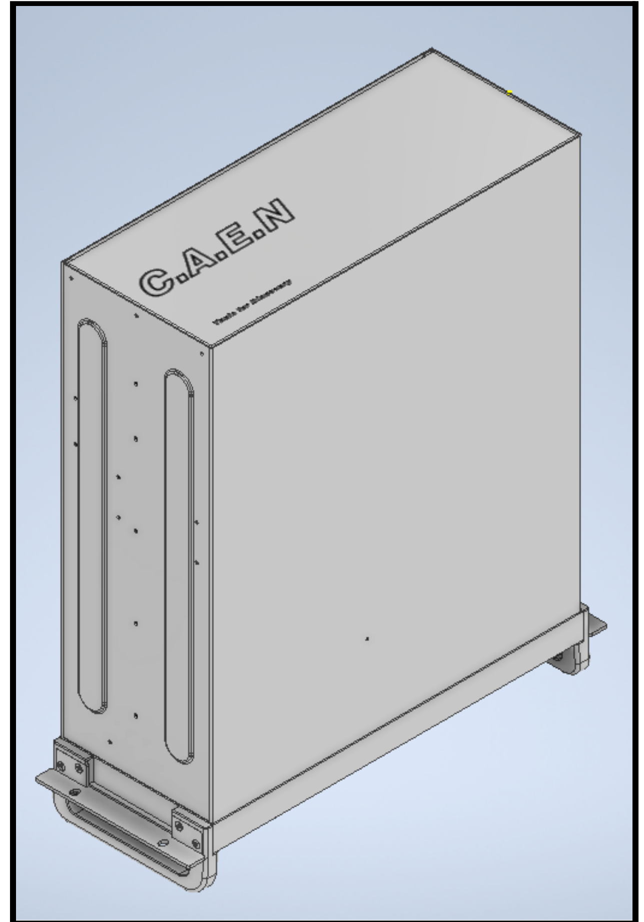
The EASY3000 or the Embedded Assembly SYstem is the new CAEN power supply solution for operation in magnetic fields and radioactive environments. Though designed for harsh environments, the EASY3000 modules can work also in normal conditions with excellent performance. The EASY3000 crate is designed to house Power Supply and ADC boards of the EASY3000 family. It is powered by external 48 V DC.

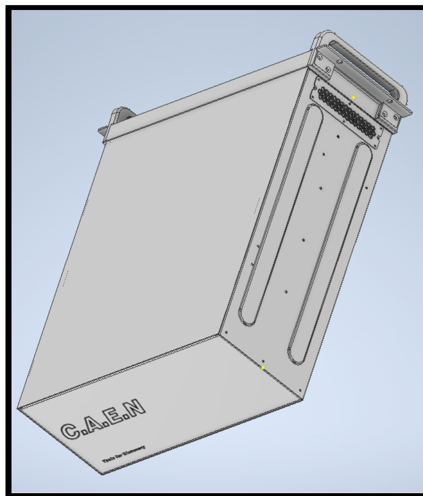


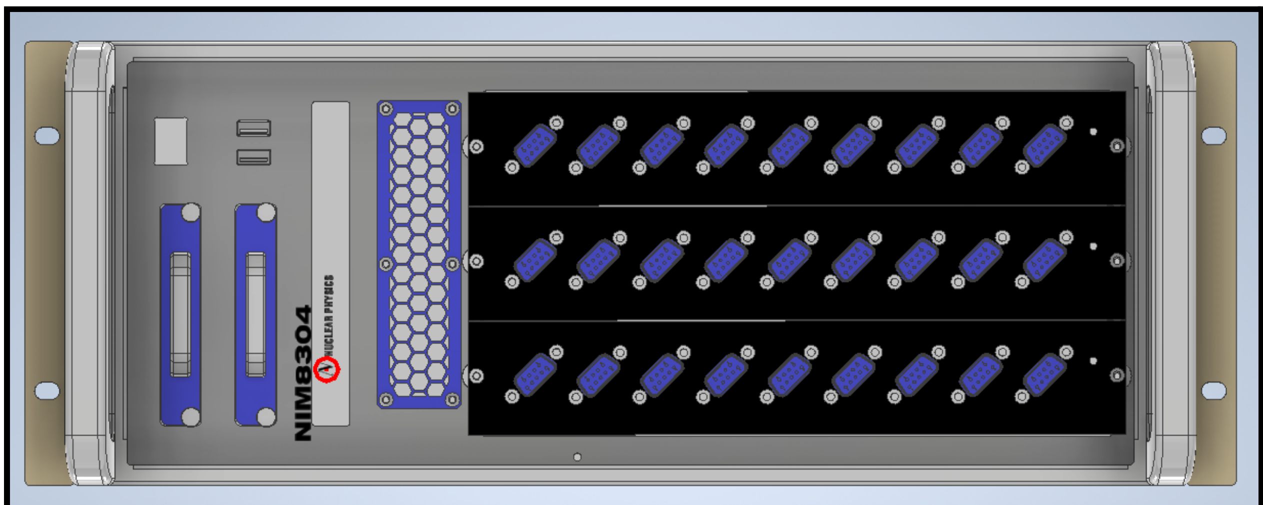


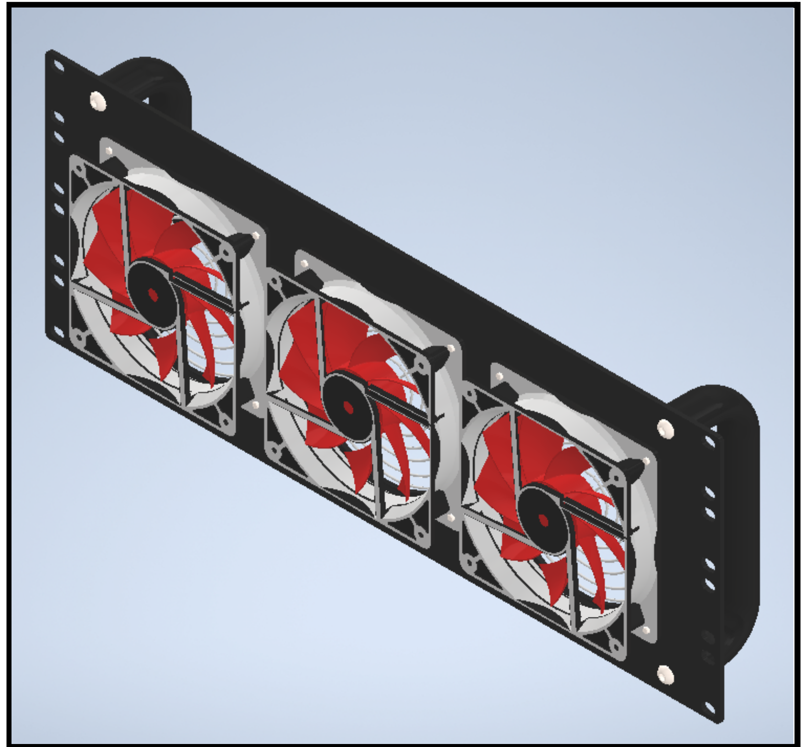
3. NIM8304.

The CAEN Mod. NIM8304 is a 7U (5+2) full size NIM crate (19″-12 slot) with pluggable low noise switching power supply.
The output power is up to 2000W (2000 W @ 220 Vac, 1000 W @ 100 Vac).
The units are ventilated with pluggable 2U fan units.
Safety features include: Short circuit protection, Over / Under voltage protection, Over temperature protection.



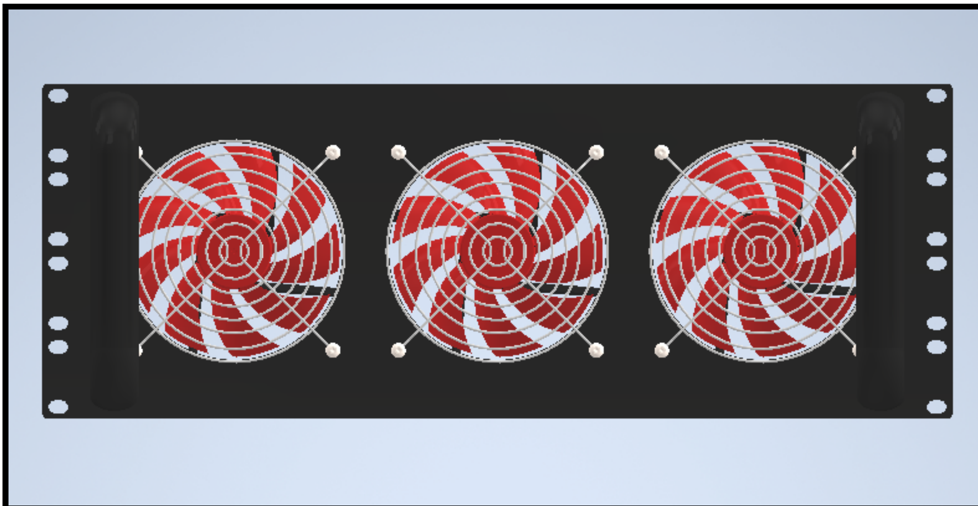


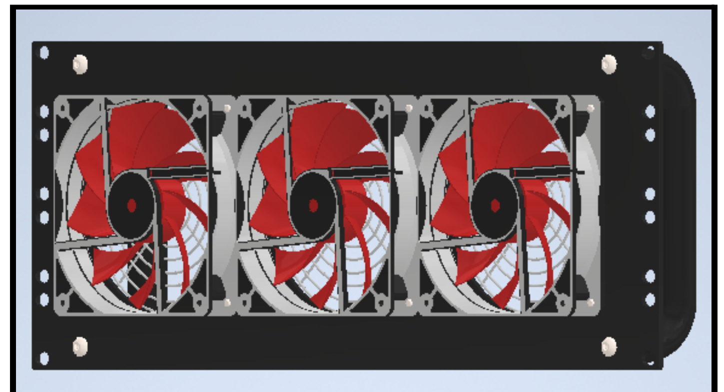




4. **2U Server Fan.**

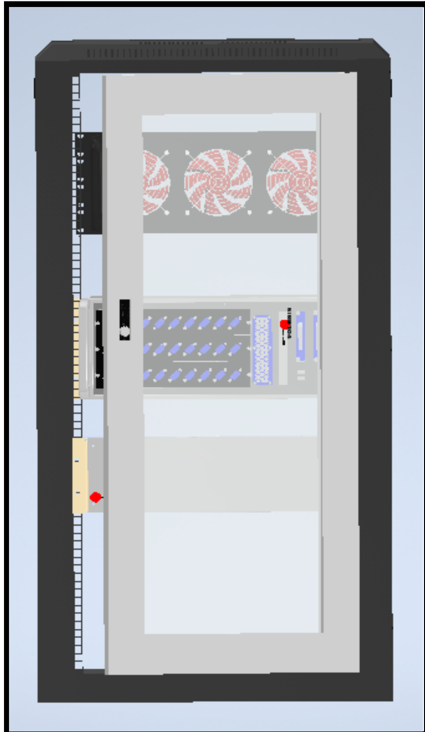
The 2U Server Fan unit is an external plugable cooling unit for the NIM8304 crate unit. It is fixable in the 19” crate design and is mountable in 2U (2 rack units). The design for the server fan selected, has a set of 3 fans arranged next to each other to maximise the effect of cooling.



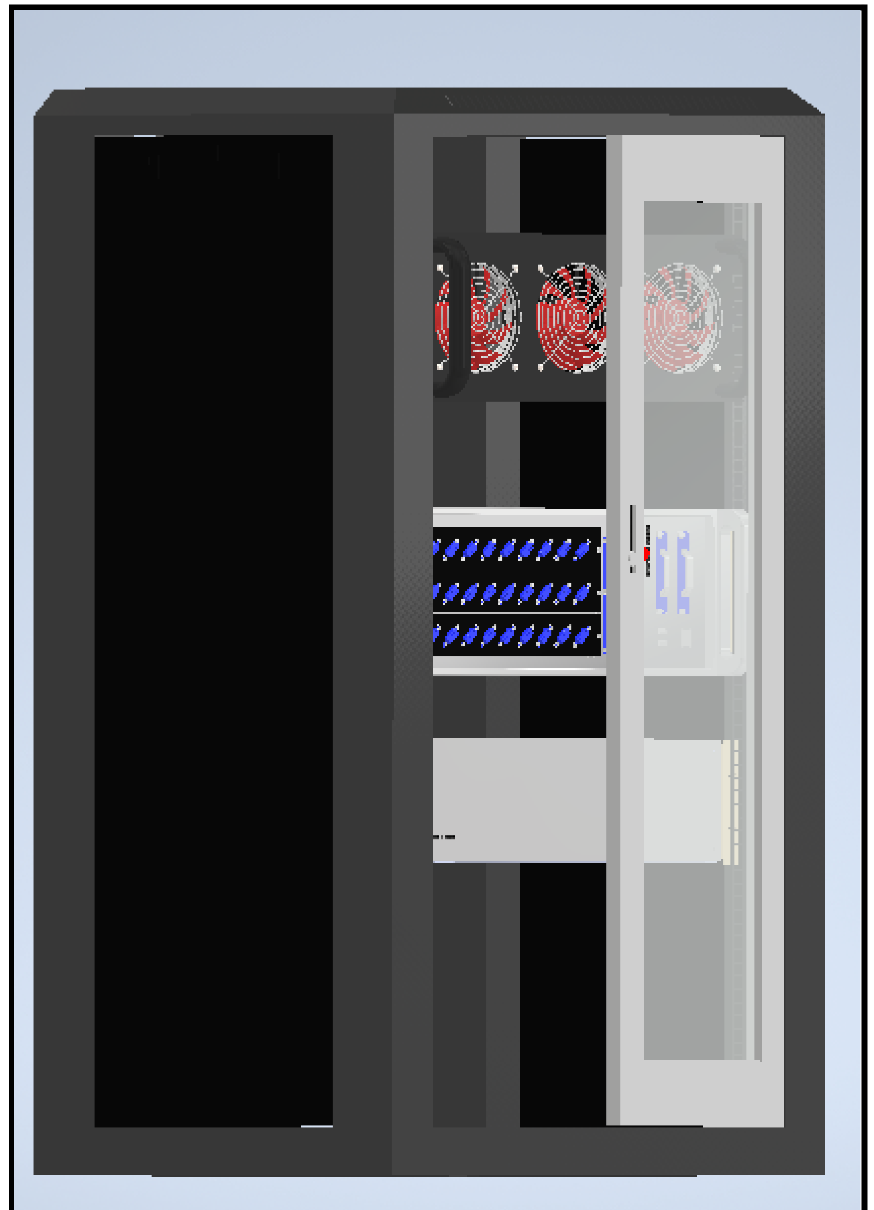


Final RACK Cabinet Assembly

The final RACK Cabinet Assembly consists of all the components mentioned above, arranged in a specific order and mounted to the 19” rack system.



The RACK System CAD rendering

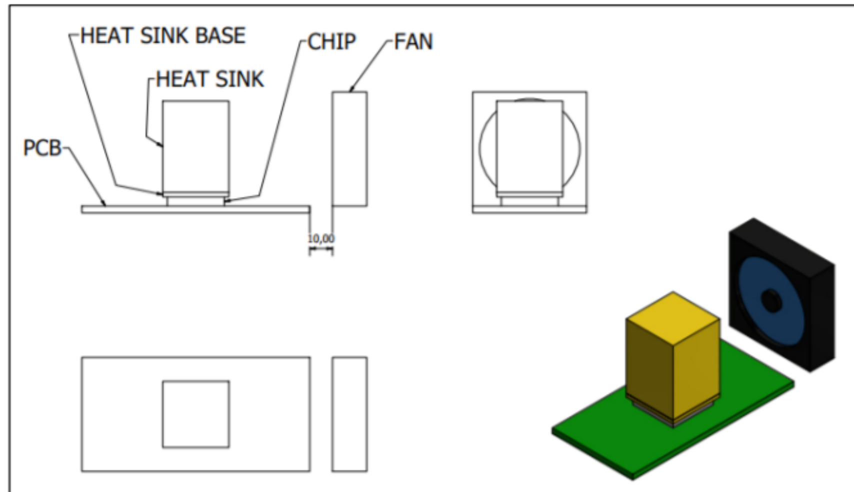


Future Prospectus

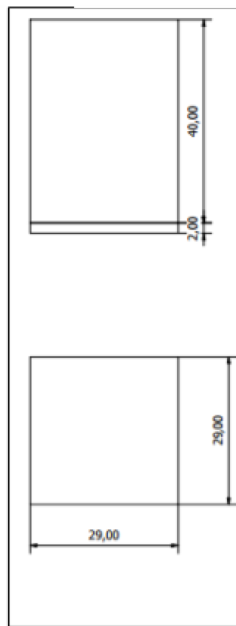
The future prospectus of this computer aided design of the RACK cabinet is broad. It will be helpful in running many kinds of simulations which will help us better understand the physics of the design and find solutions to engineering problems.

To narrow down the future prospect of this 3D model with respect to the project, it will be very useful in performing heat transfer simulations of the entire RACK cabinet system and help us better the heat instability issues and work on more advanced methods of cooling. This will better the conditions of operation of the sensitive electronic instruments housed inside the RACK body, and inturn improve the efficiency of the components.

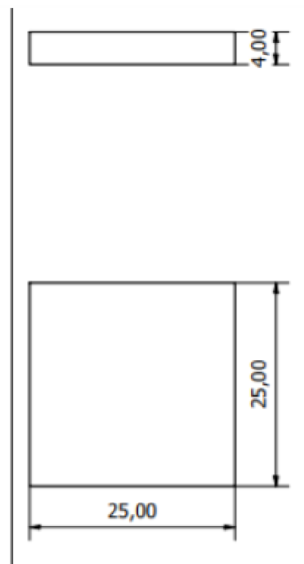
APPENDIX A: Technical Documents



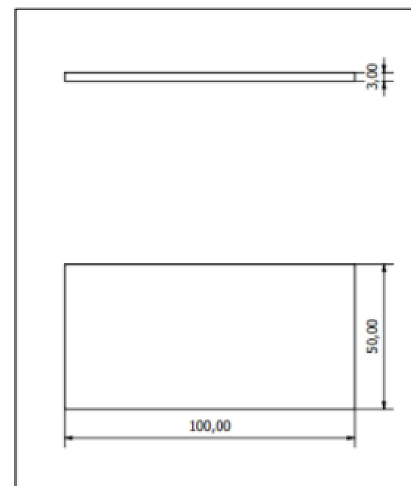
3D Module



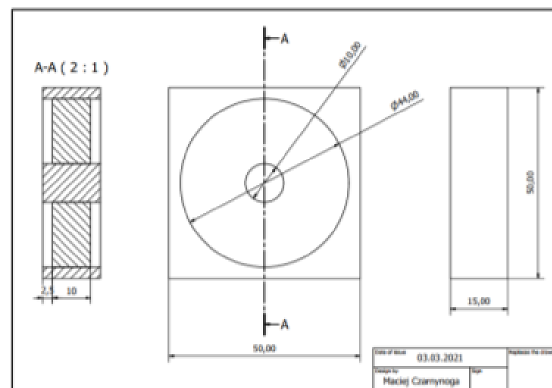
Heat Sink



Chip



PCB



Fan unit

Acknowledgement
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  https://www.caen.it/products/easy3000/
- NIM8304
  https://www.caen.it/products/nim8304/
- Literature Referred
  https://knowledge.autodesk.com/support/inventor/learn-explore/caas/CloudHelp/cloudhelp/2019/ENU/Inventor-Help/files/GUID-38FD0129-6A24-40D5-8596-B354344F4F91-htm.html
- PLOT Dataset:
  https://drive.google.com/file/d/1cxNtDKS5muxDl0CEOcobnRlbRgoZN-j6/view?usp=sharing