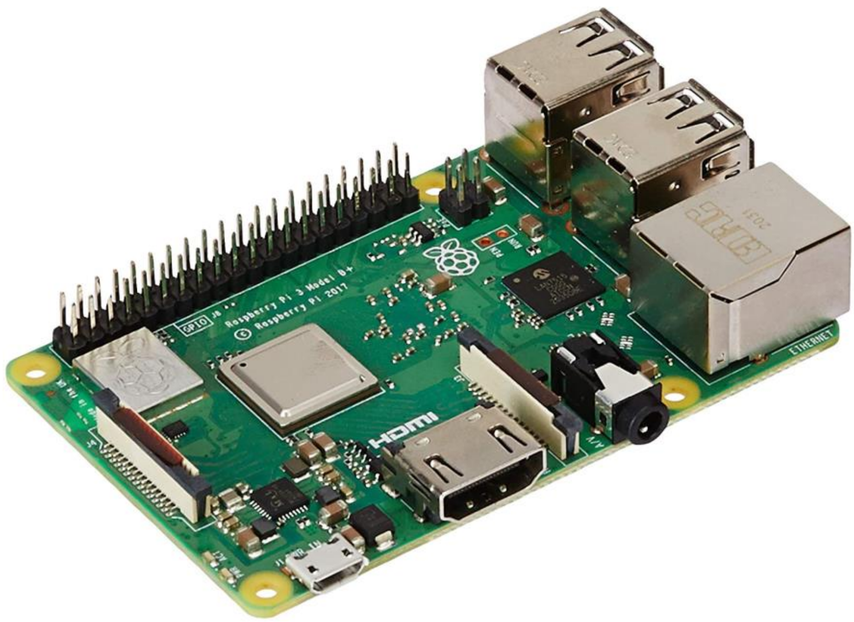
Designing a case for raspberry pi 3b+ and performing stress analysis, drop test, thermal and fluid simulation to determine effectiveness of the design.

Introduction

Raspberry Pi is a series of small single-board computers (SBCs) developed in the United Kingdom by the Raspberry Pi Foundation in association with Broadcom.[The Raspberry Pi project originally leaned towards the promotion of teaching basic computer science in schools and in developing countries. The original model became more popular than anticipated, selling outside its target market for uses such as robotics. It is widely used in many areas, such as for weather monitoring, because of its low cost, modularity, and open design. It is typically used by computer and electronic hobbyists, due to its adoption of HDMI and USB devices.

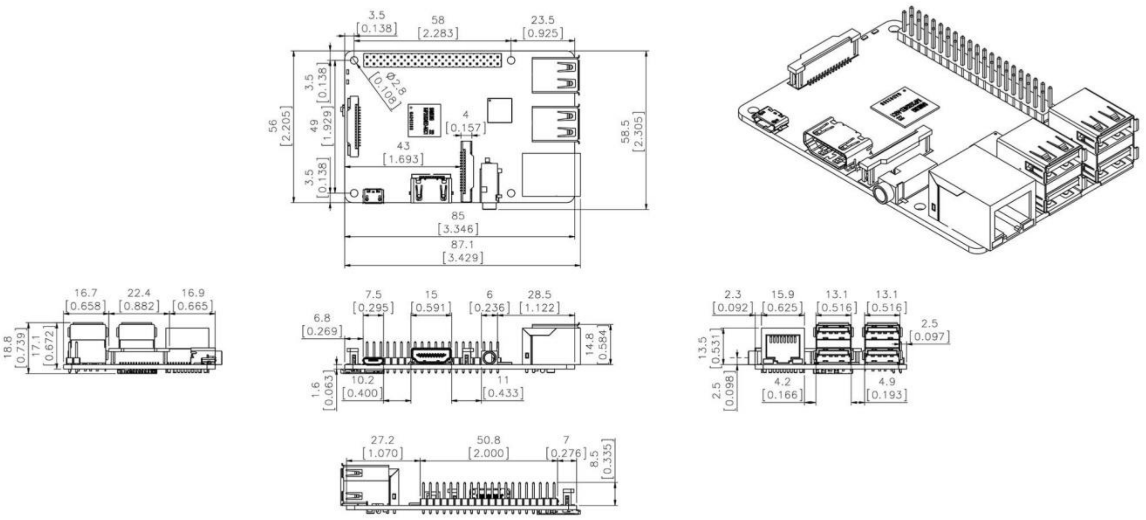


Objective

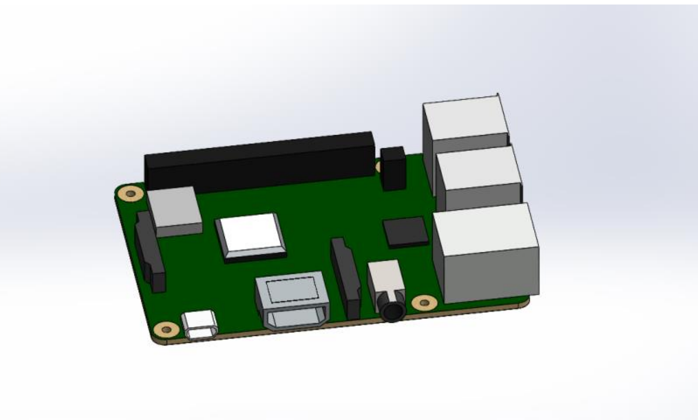
We will be
1- modeling raspberry pi 3b+
2- designing and modeling the case for the microprocessor
3- devising effective cooling solutions
4- performing stress-strain analysis ,drop test to ensure the strength of the case
5- performing thermal and fluid simulations to ensure temperatures stay well below manufacturer recommended temperatures even at full capacity.

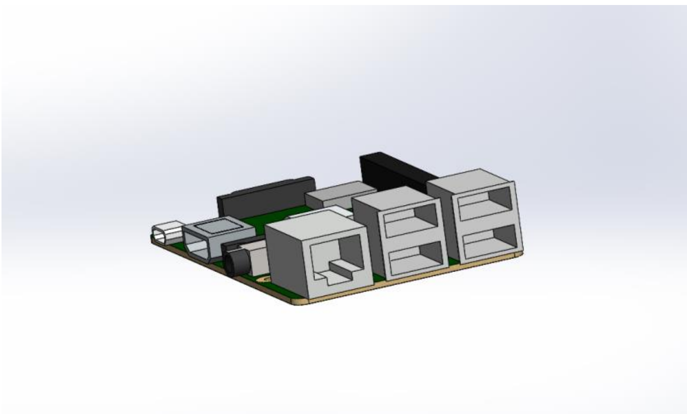
1 - Modeling the raspberry pi 3b+

We will be using technical drawings from the manufacturer to model the microprocessor.



(All models used in the report are available on my grabcad profile- link)





2- Designing and modeling the case for the microprocessor

The following design consideration made while modeling the case

-it should be strong enough to support a reasonable force that is applied on it and protect the microcontroller.

-it should be able to survive drops from a reasonable height.

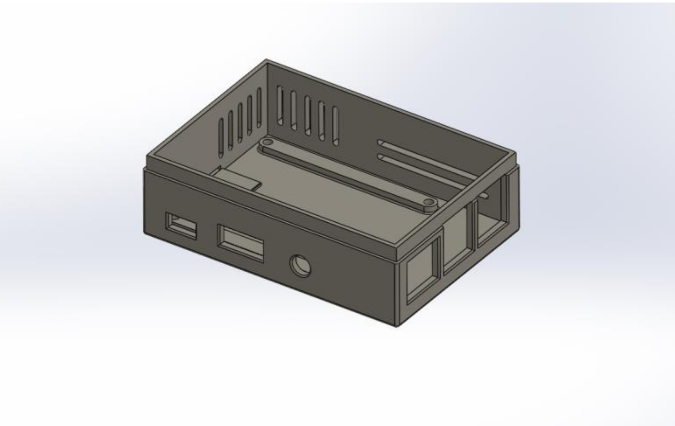
-it needs to have appropriate openings to be able to access all ports of the raspberry pi (usb,dc jack,sd card,Ethernet etc).

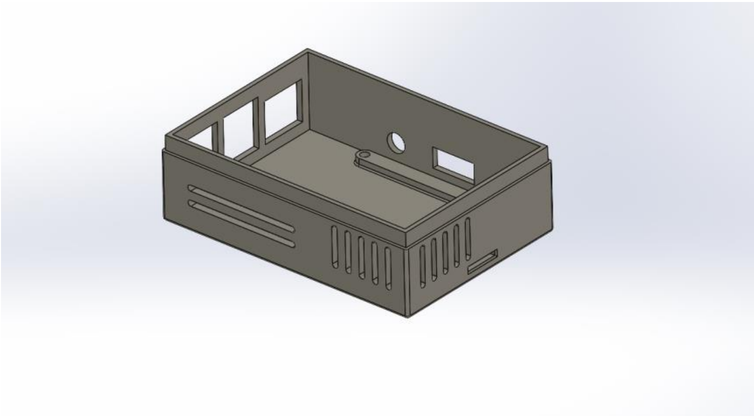
-needs to be compatible with various cooling methods later on(heatsinks and fans).

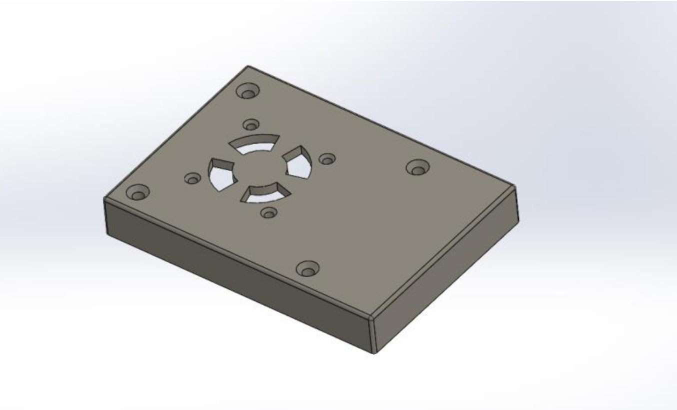
- The material would be delrin.

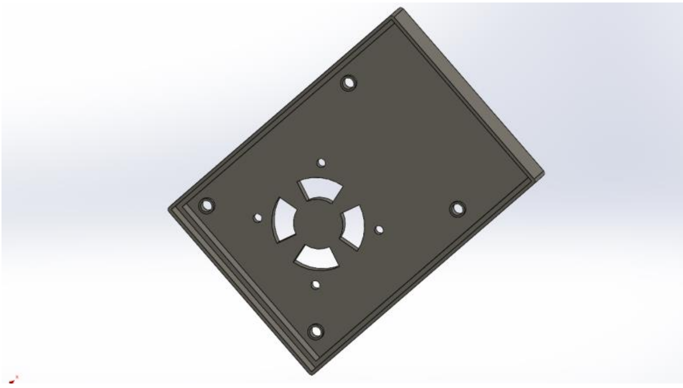
Given these constraints the following design was finalized

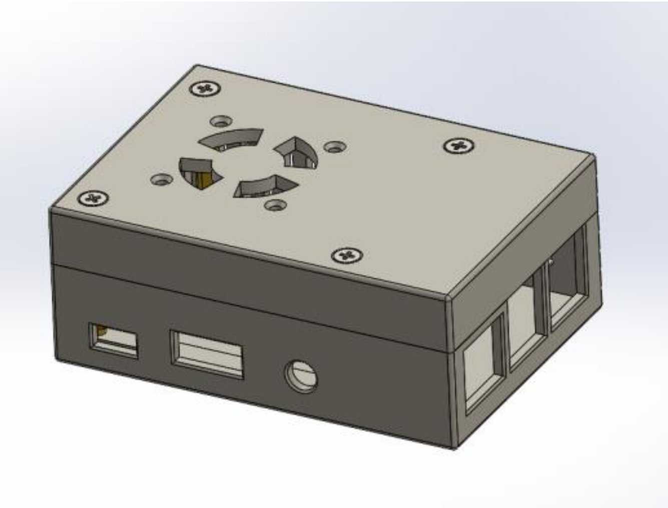
(All models used in the report are available on my grabcad profile- [link]())

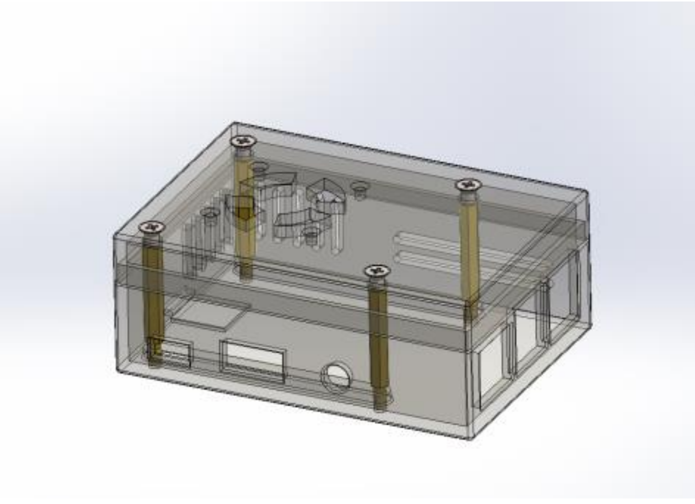










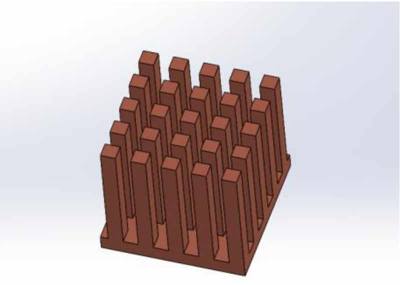


3- Devising effective cooling solutions

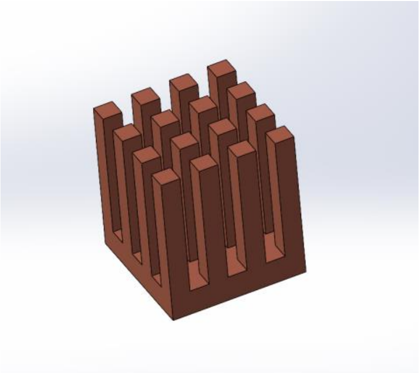
For cooling we will be using two steps in this design.

1) We will be using pin fin heat sinks. A pin fin heat sink is a heat sink that has pins that extend from its base. The pins can be cylindrical, elliptical or square. A pin is by far one of the more common heat sink types available on the market. In general, the more surface area a heat sink has, the better it works. However, this is not always true. The concept of a pin fin heat sink is to try to pack as much surface area into a given volume as possible. It also works well in any orientation.

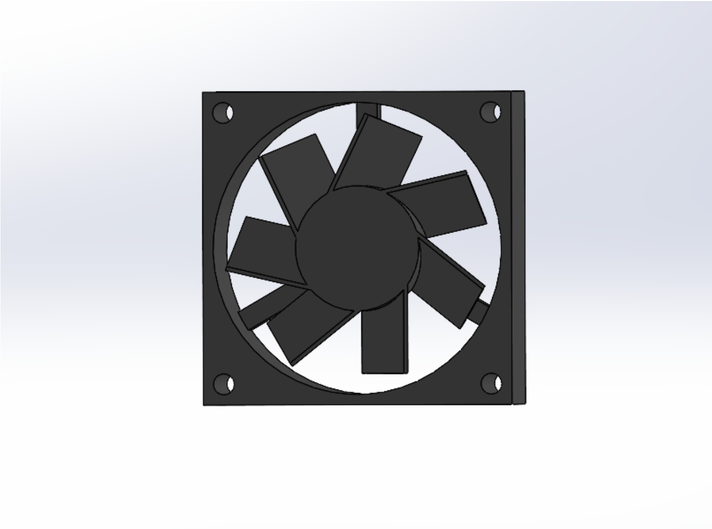
   2) We will be using the 30x30x8mm fan slot that we made earlier to install a Papst 255h fan and be using the other slots for ventilation.



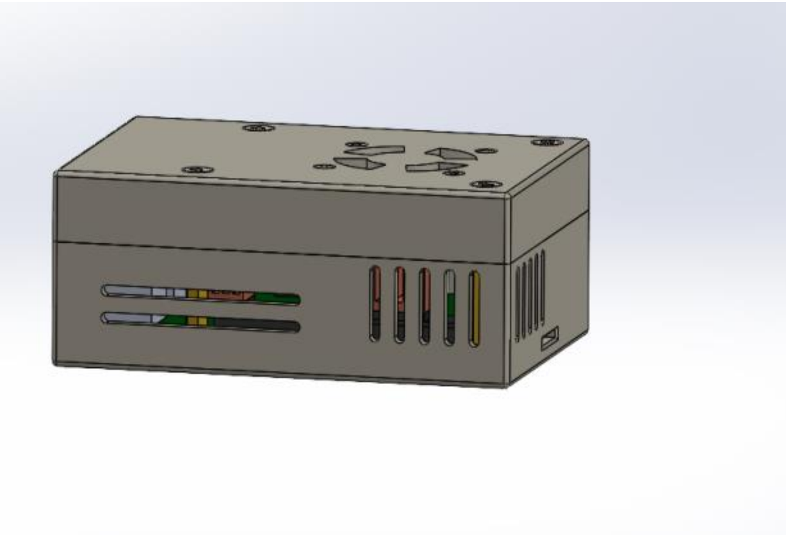
14.28x14.28 mm heat sink for cpu

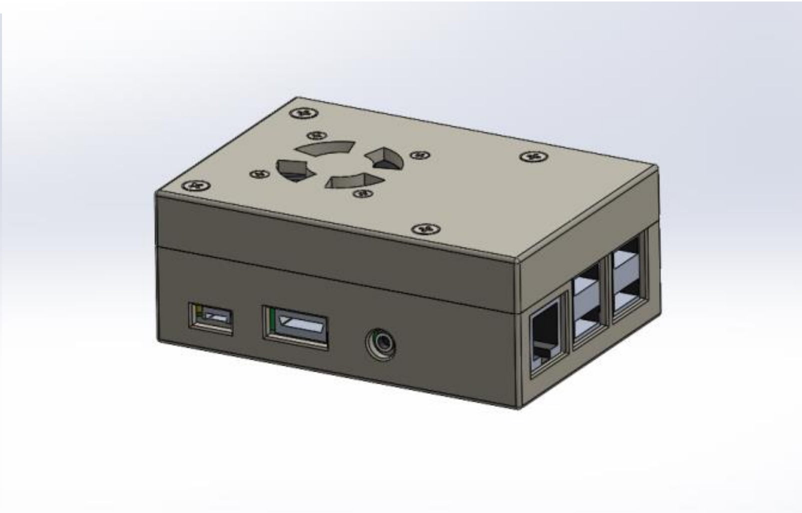


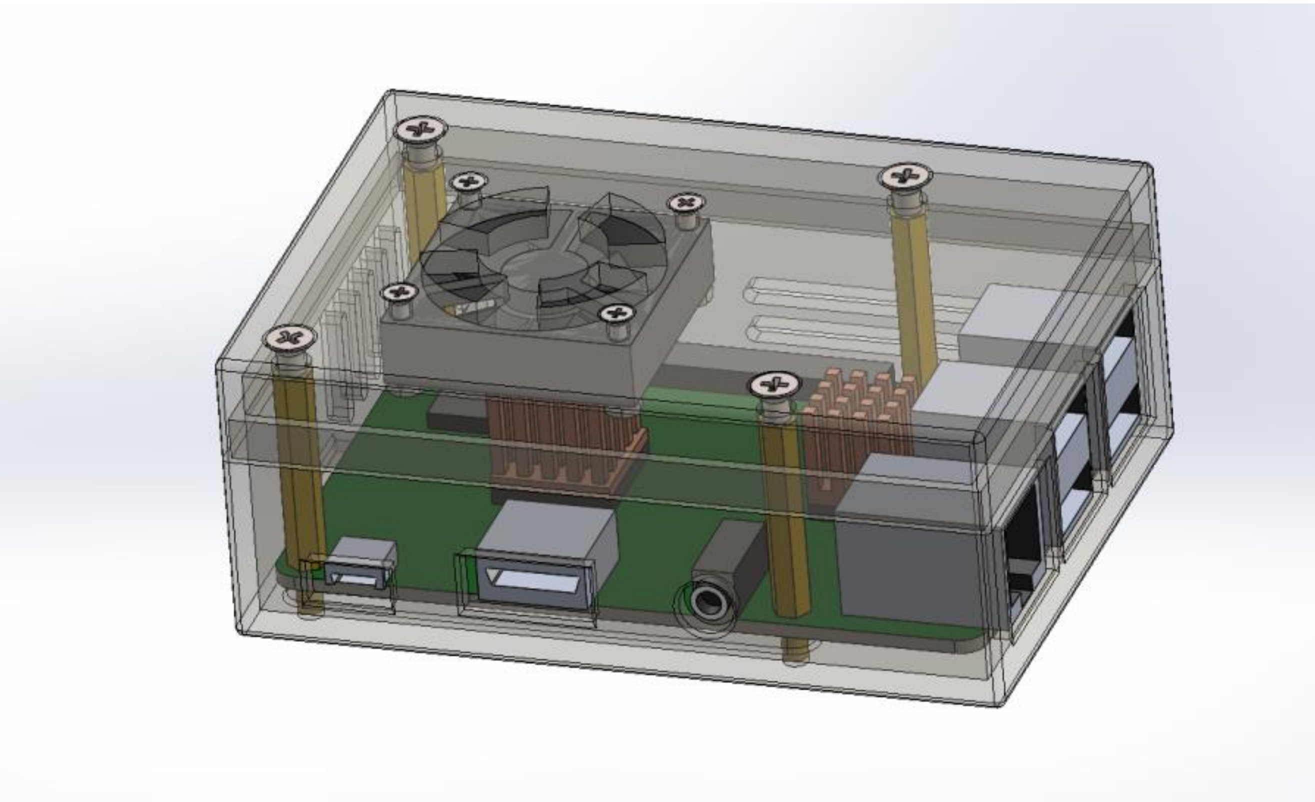
10.5x10.5mm heat sink for network chip



Images of final assembly of the cad model







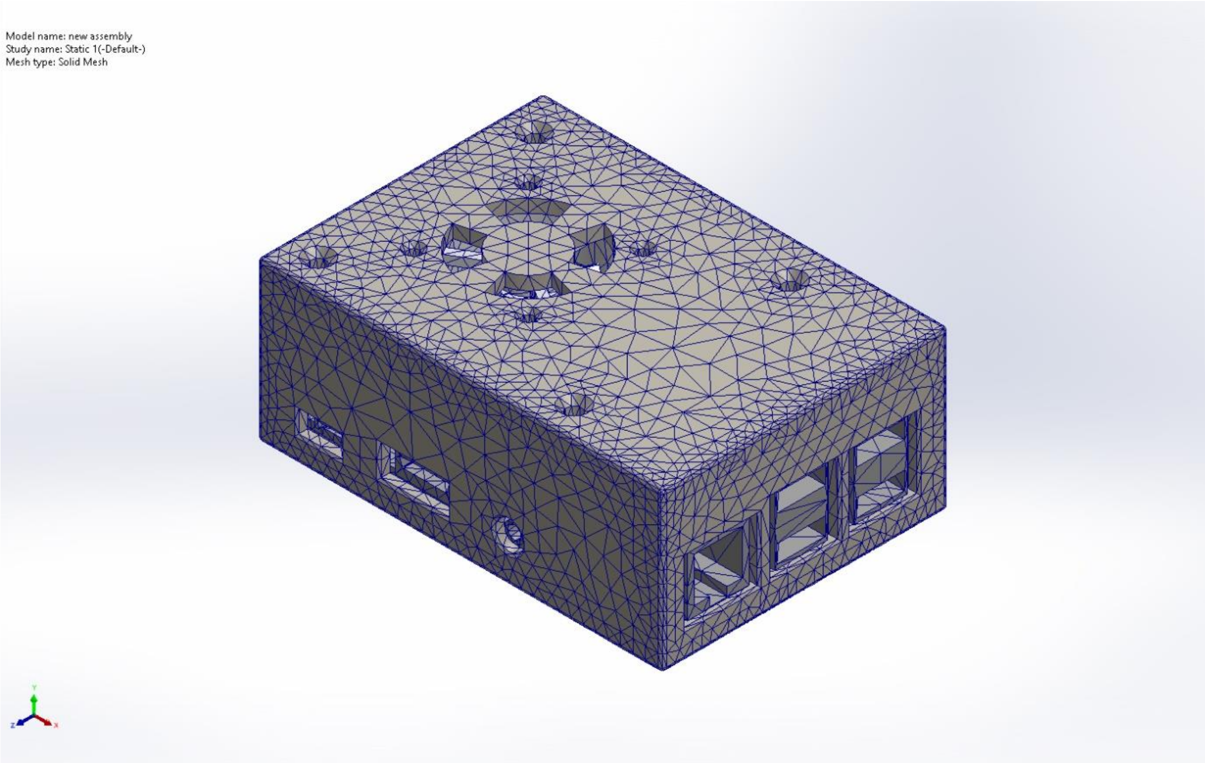
4- Performing stress-strain analysis, drop test to ensure the strength of the case

Stress-strain analysis

1) For the stress strain analysis we shall be applying a force of 50kg or 500 N to the top face of the assembly while fixing the bottom face.
2) Component contacts will be used for the nut and bolt.
3) No penetration will be used for global contact.

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	11.7492 mm
Minimum element size	2.13622 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off



Below are the stress and strain plots(von mises) of the assembly, the red areas do not indicate stresses above the failure point the limits were chosen in such a way to highlight the points of stress concentration

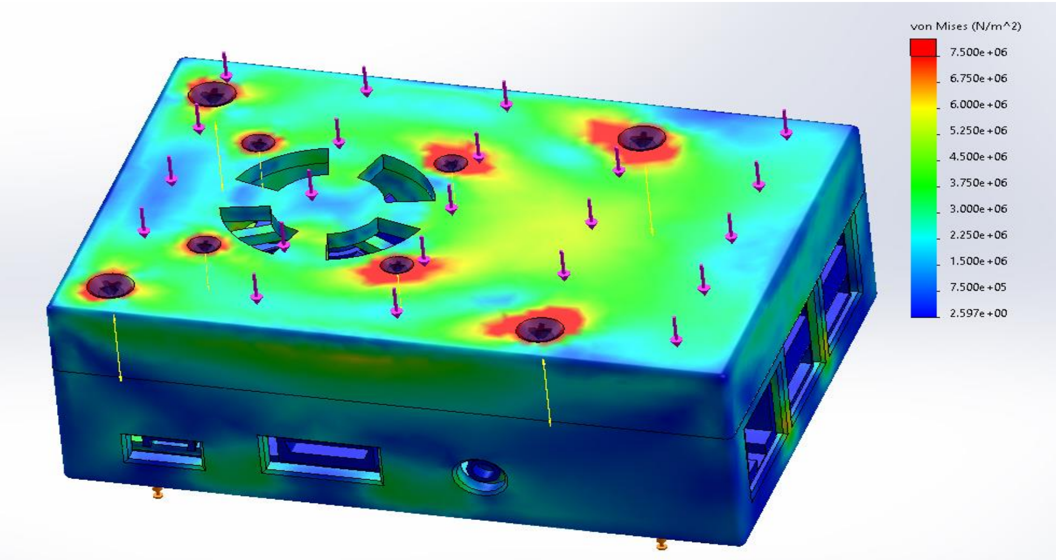


Figure 1

Here we see the stress plot of the assembly.(red areas do not indicate failure only for representation)

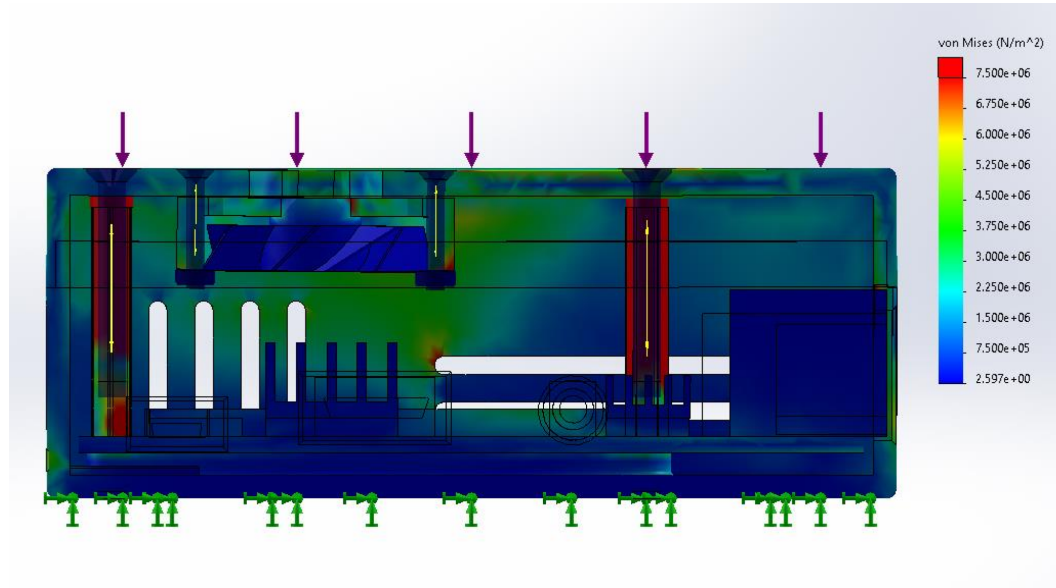


Figure 2

Here we see the stress plot of the assembly. It is a section plot of the front view

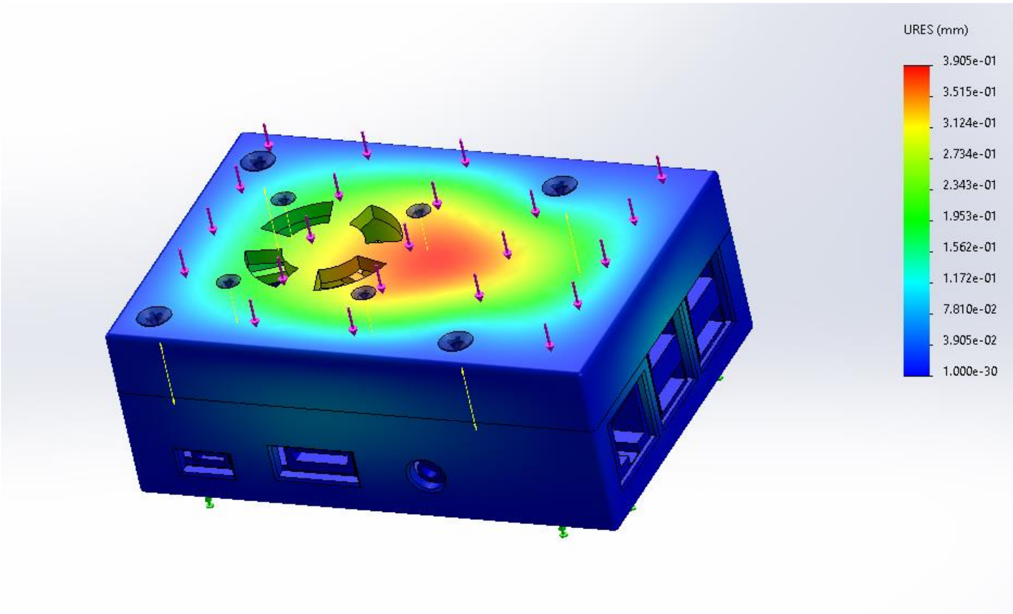
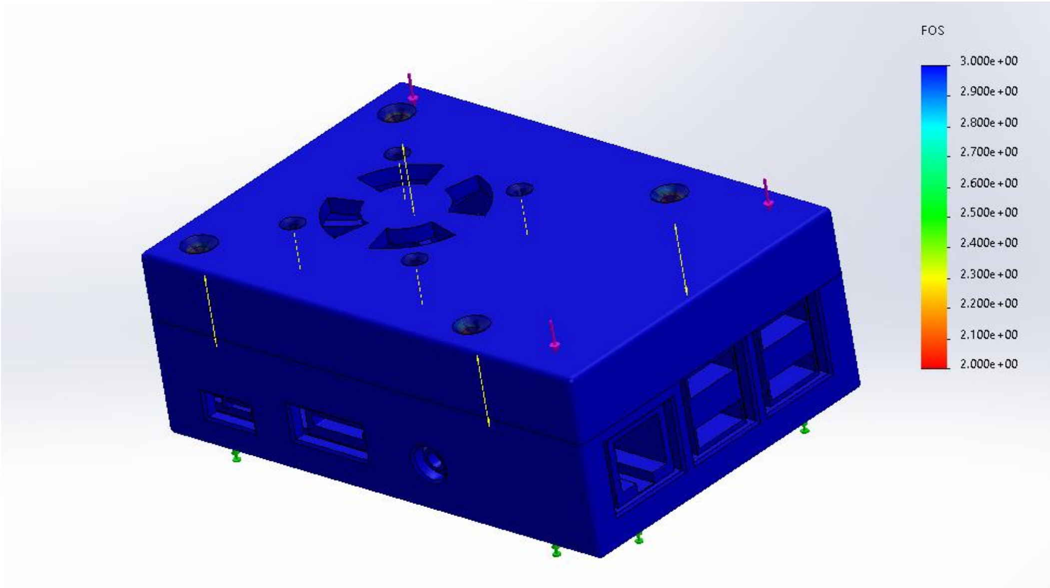


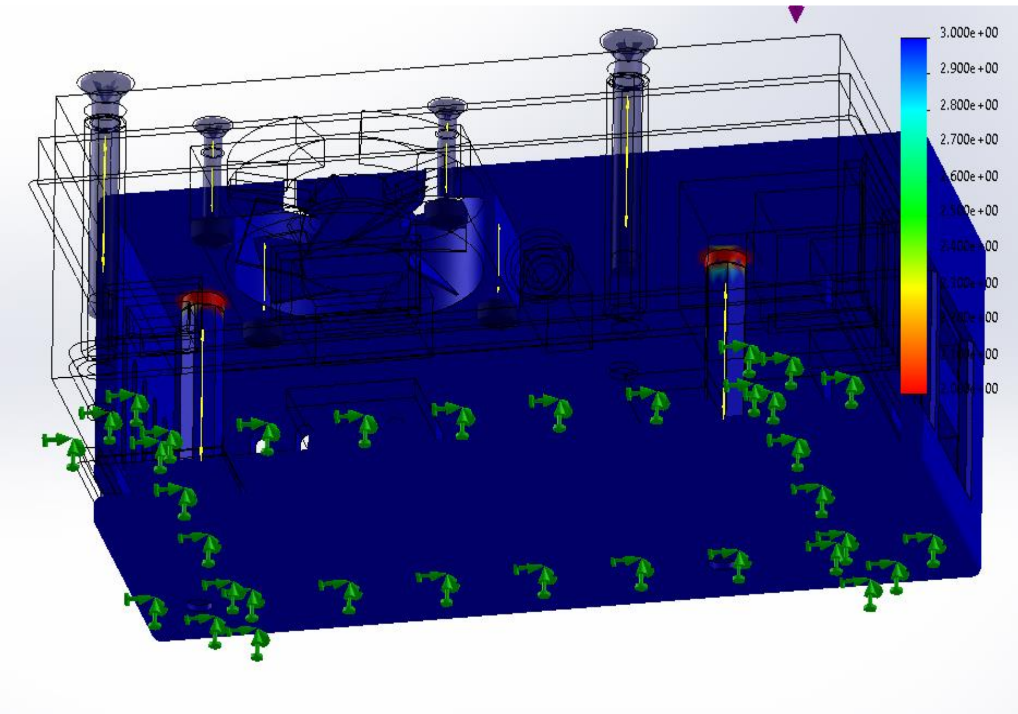
Figure 3

Here we see the strain plot.

The max strain as shown is 0.39 mm near the center of the case.

Now we shall analyze the factor of safety plot , we can see that the factor of safety of most areas on the model is greater than 3. We see one region with factor of safety below 2. The reason of this could be large concentration stress due to small contact surface area between the case and the metal standoffs.

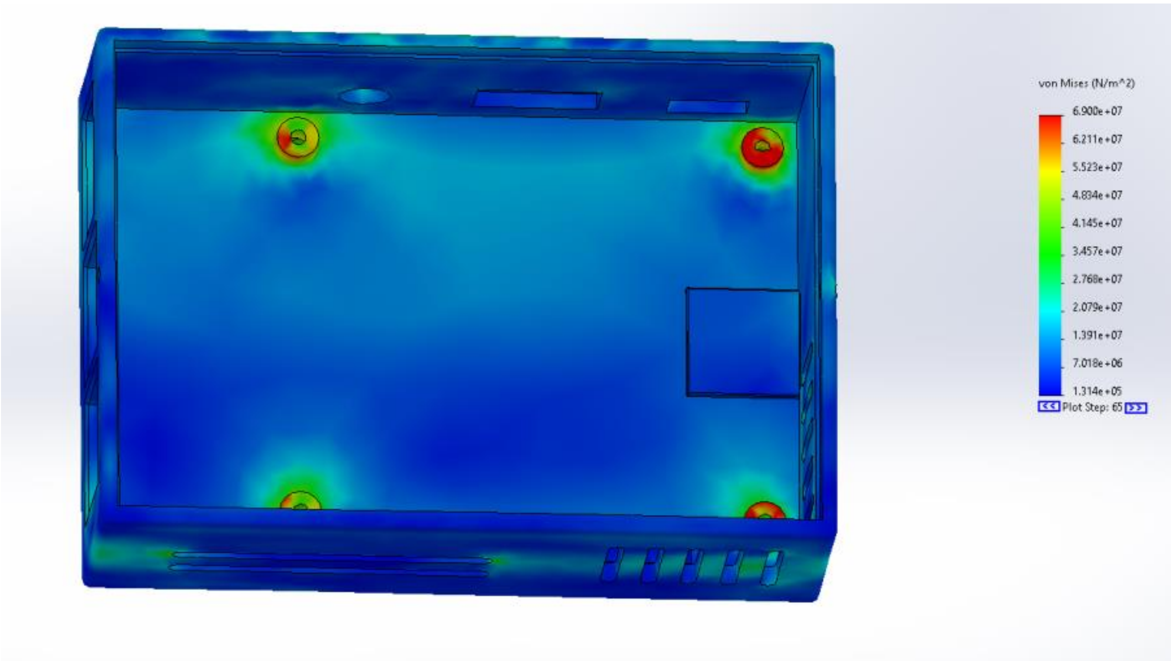




Drop test

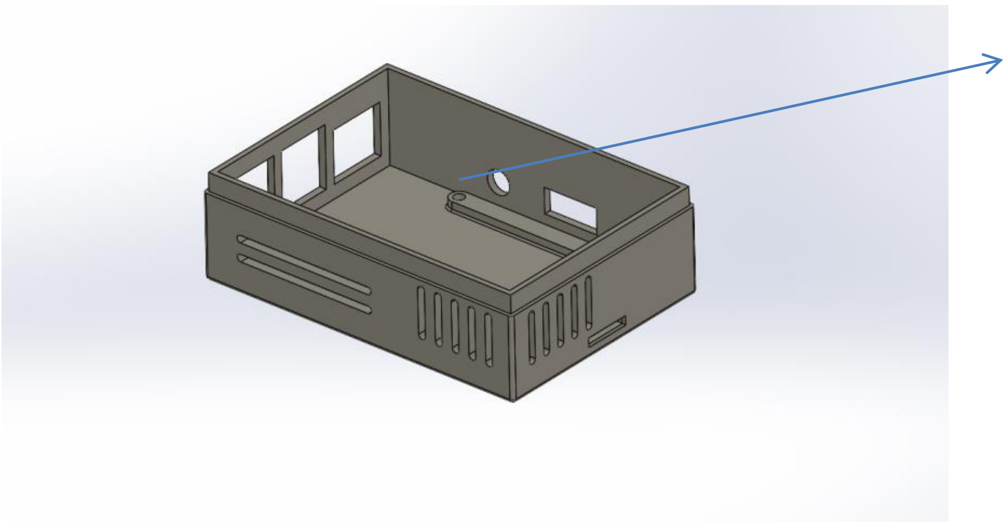
Animated stress and strain plot of drop test.

Multiple drop tests were simulated from a height of 2 meters and various orientations. Depending of the results many changes were made in the model. It wouldn't be possible to show all the changes but one such change is shown below.



The bottom part of the enclosure will fail as shown in image the extrusion where we screw the microprocessor. This might be due to it being the only contact area for the entire board. One possible way to reduce the stress it experiences is to add more surface areas between the microprocessor and the enclosure either by increasing the diameter of the extrusion or by adding other supports along the perimeter of the microprocessor.

Model after making appropriate change



The contact is changed to increase the surface area.

5-Performing thermal and fluid simulation

Initial Conditions

Thermodynamic parameters	Static Pressure: 101325.00 Pa Temperature: 303.00 K
Solid parameters	Initial solid temperature: 303.00 K
Turbulence parameters	Turbulence intensity and length Intensity: 2.00 % Length: 3.600e-04 m

Heat Volume Sources

VS Heat Generation Rate 1

Component 1 and 2	1) cpu chip-1@raspi assembly pinfin 2) network chip-1@raspi assembly pinfin
Coordinate system	Global coordinate system
Reference axis	X
Source type	Heat Generation Rate
Heat generation rate	1) 4.500 W 2) 0.500W

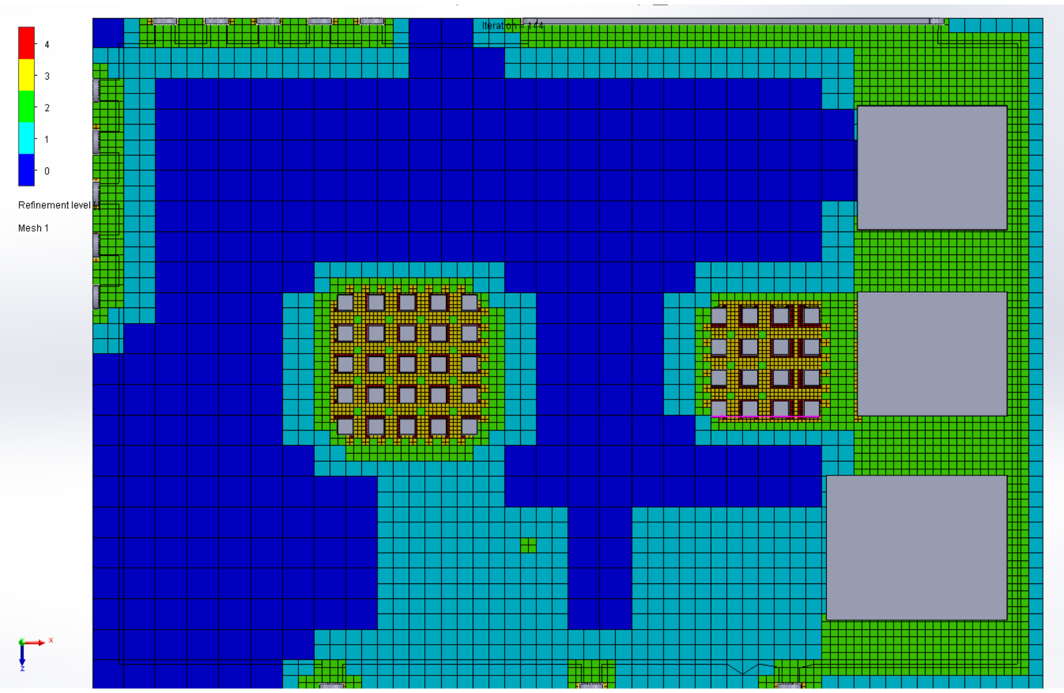
Fans

External Inlet Fan 1

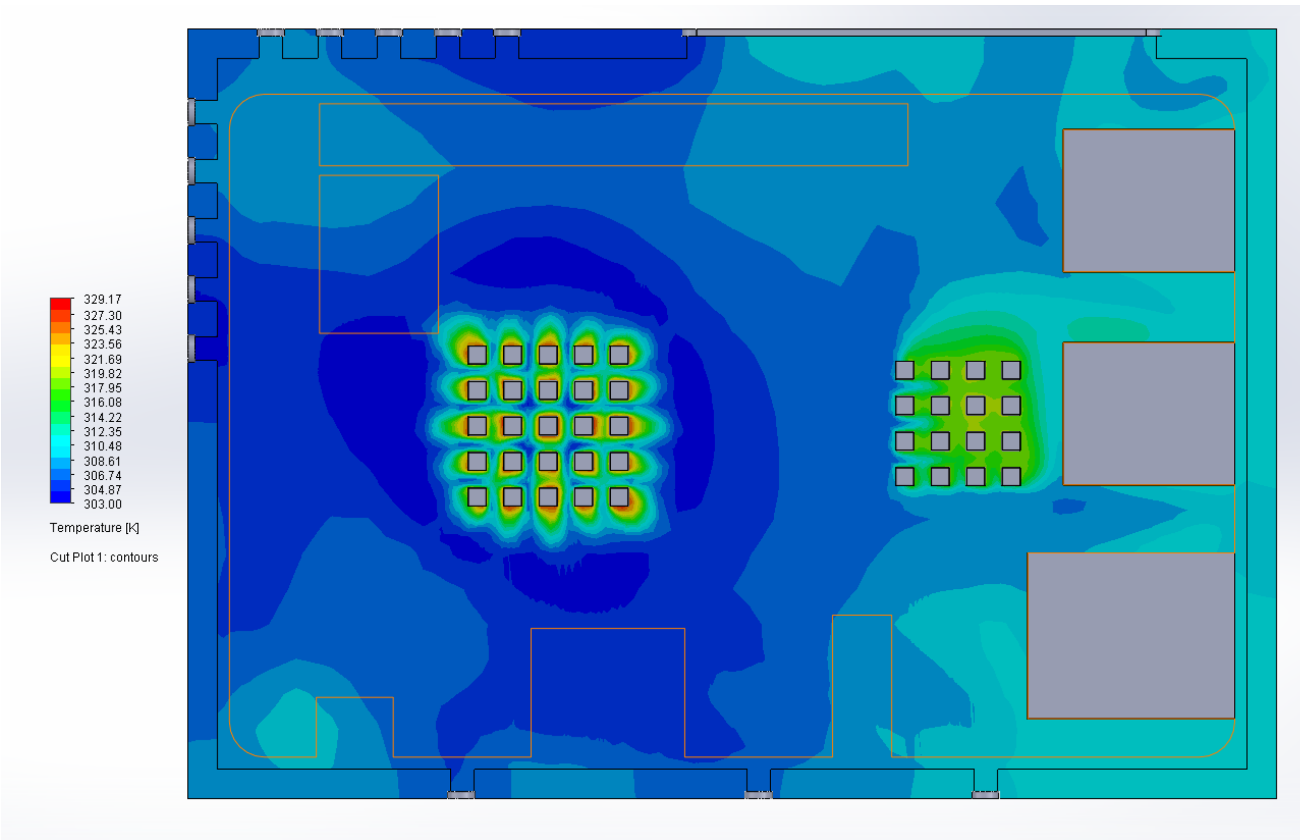
Type	External Inlet Fan
Fan curve	255H
	LID10-1/Imported1//Face
Coordinate system	Face Coordinate System
Reference axis	X
Flow parameters	Inlet flow vector direction: Normal to face
Thermodynamic parameters	Environment pressure: 101325.00 Pa Temperature: 303.00 K
Turbulence parameters	Turbulence intensity and length Intensity: 2.00 % Length: 3.600e-04 m

Results

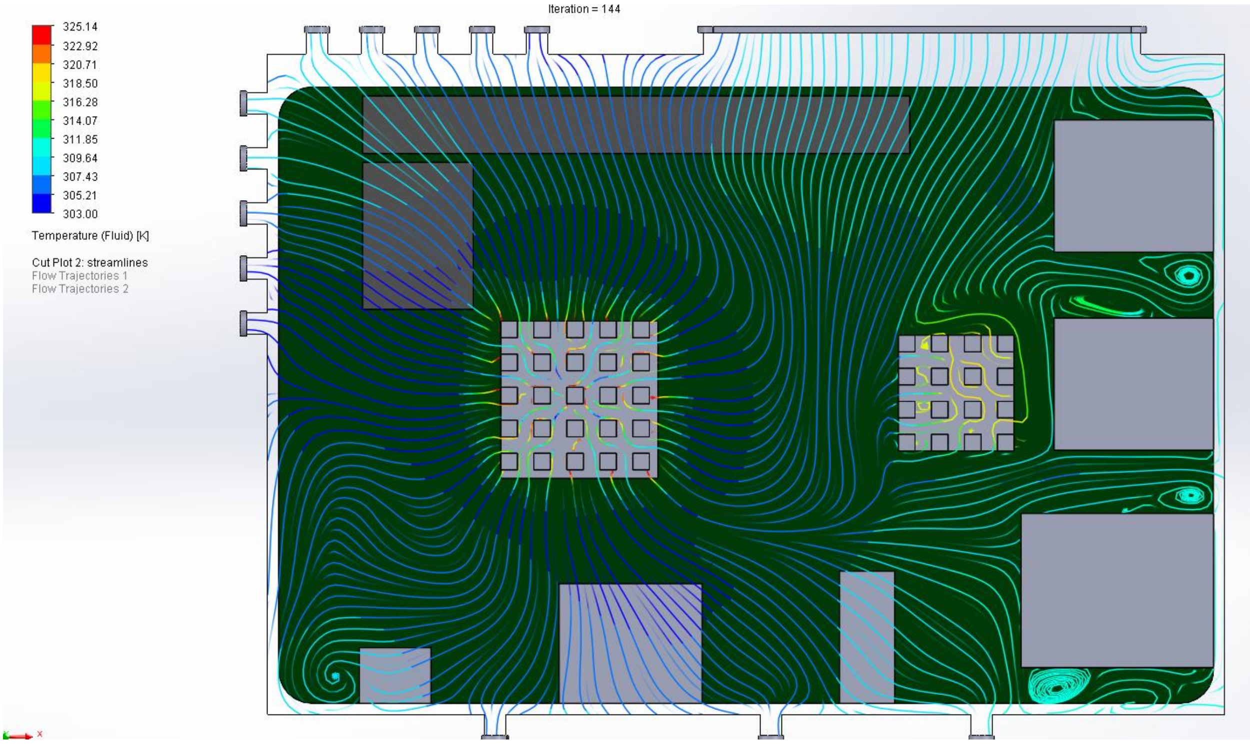
<u>Global and local mesh section view</u>

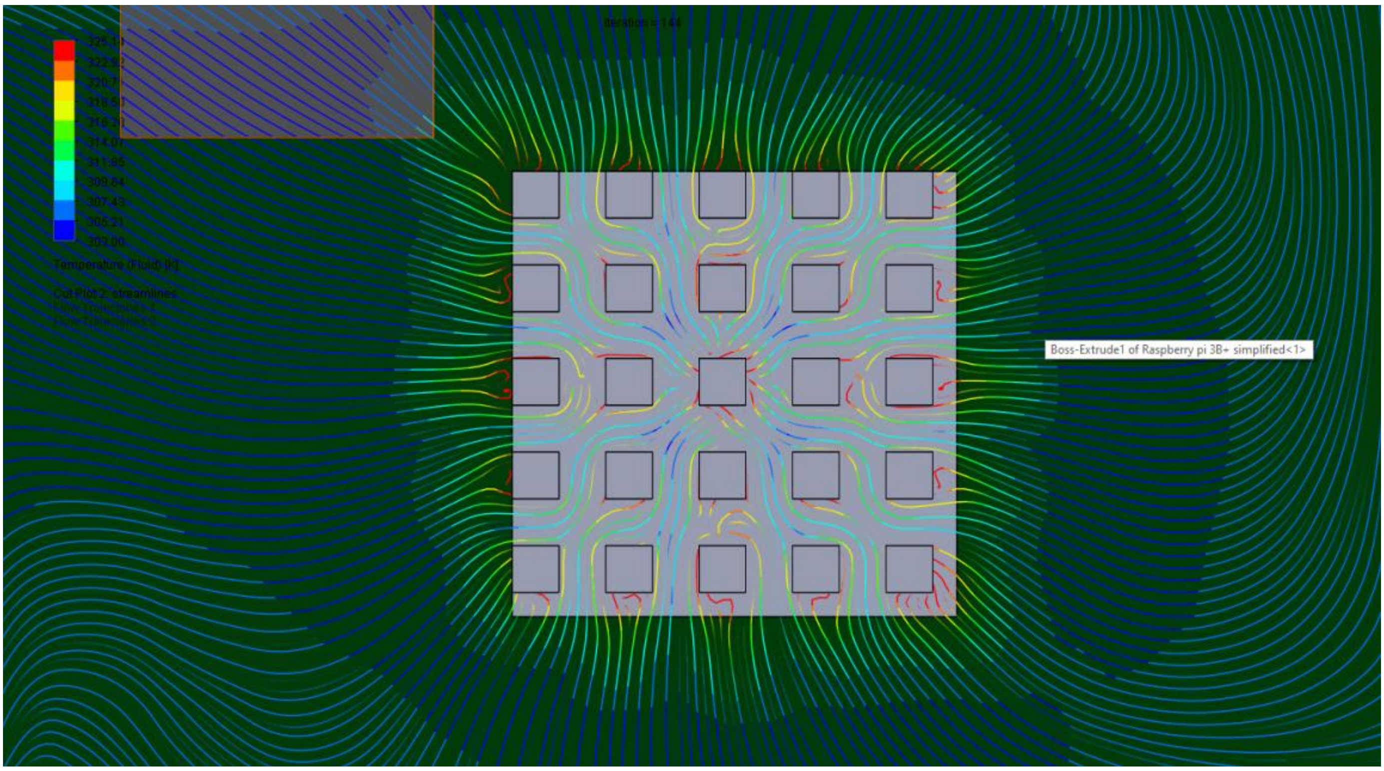


<u>Fluid temperature contour</u>

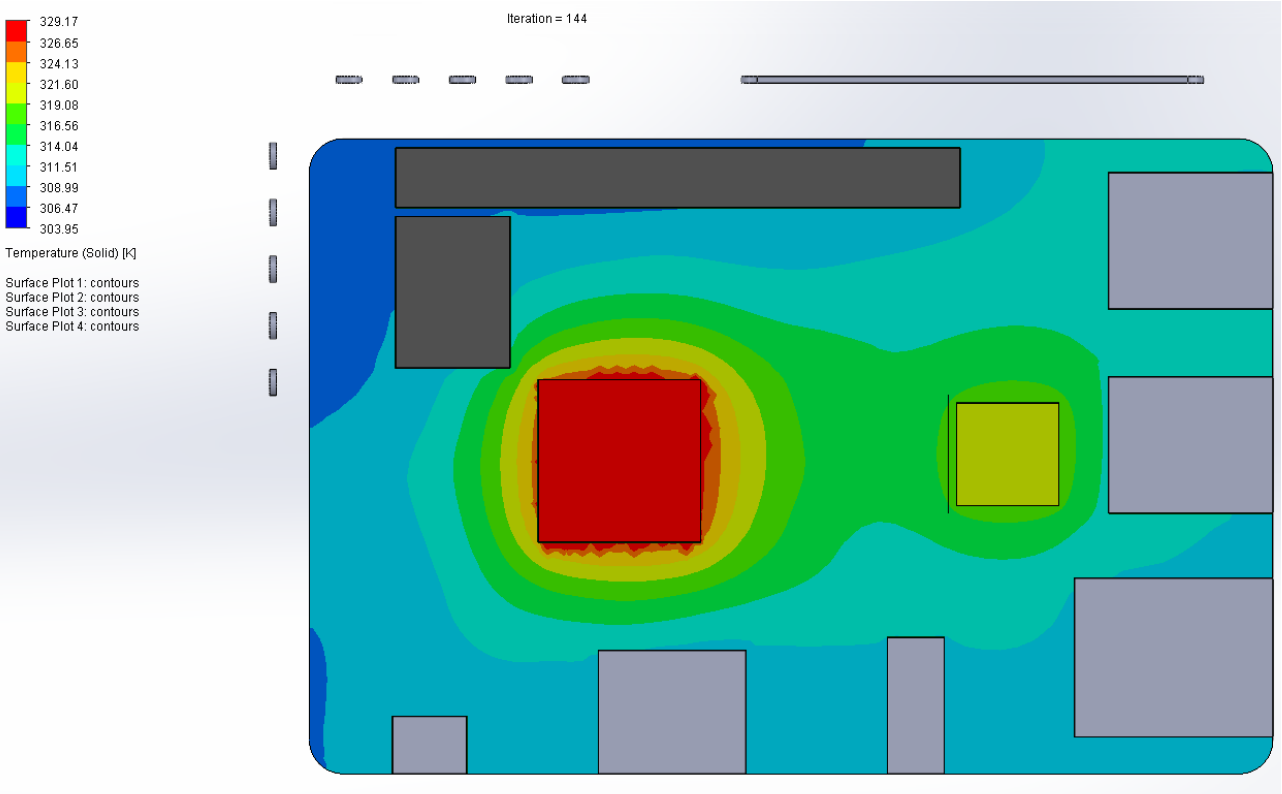


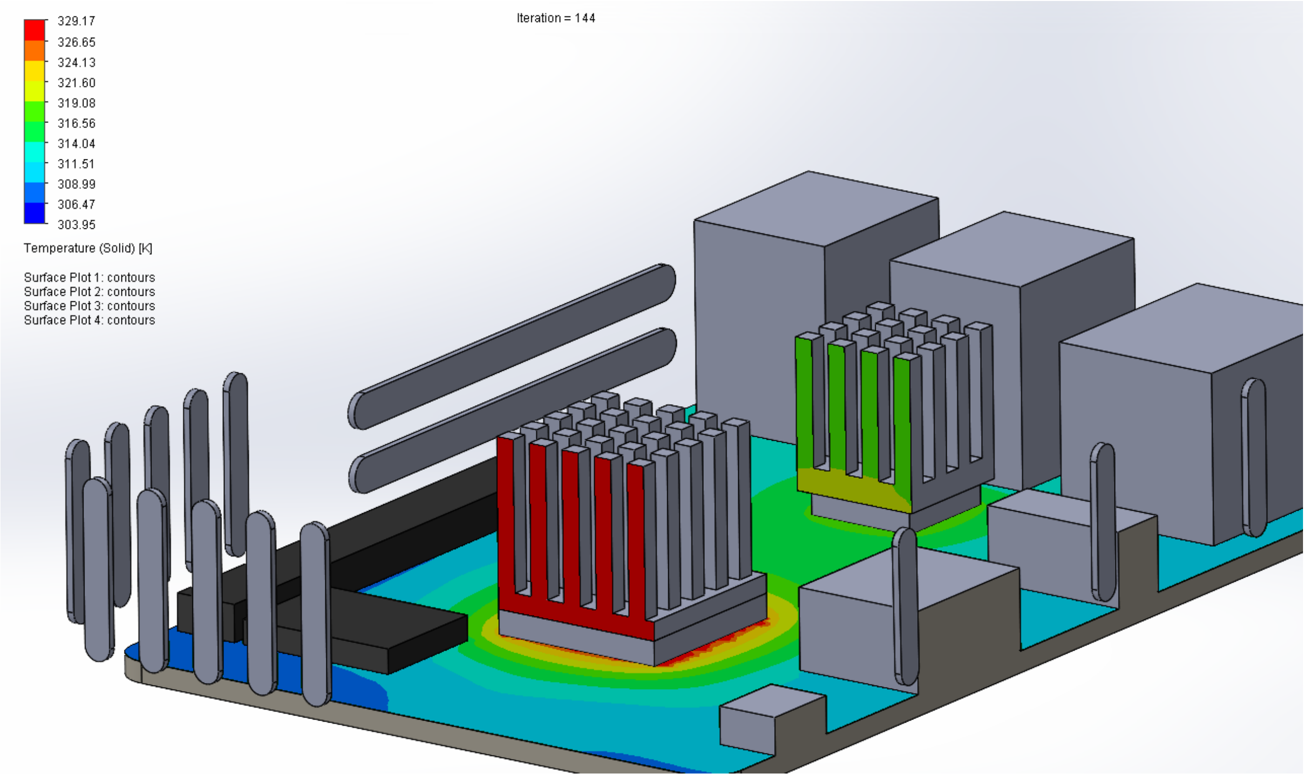
Cut plot of stream lines



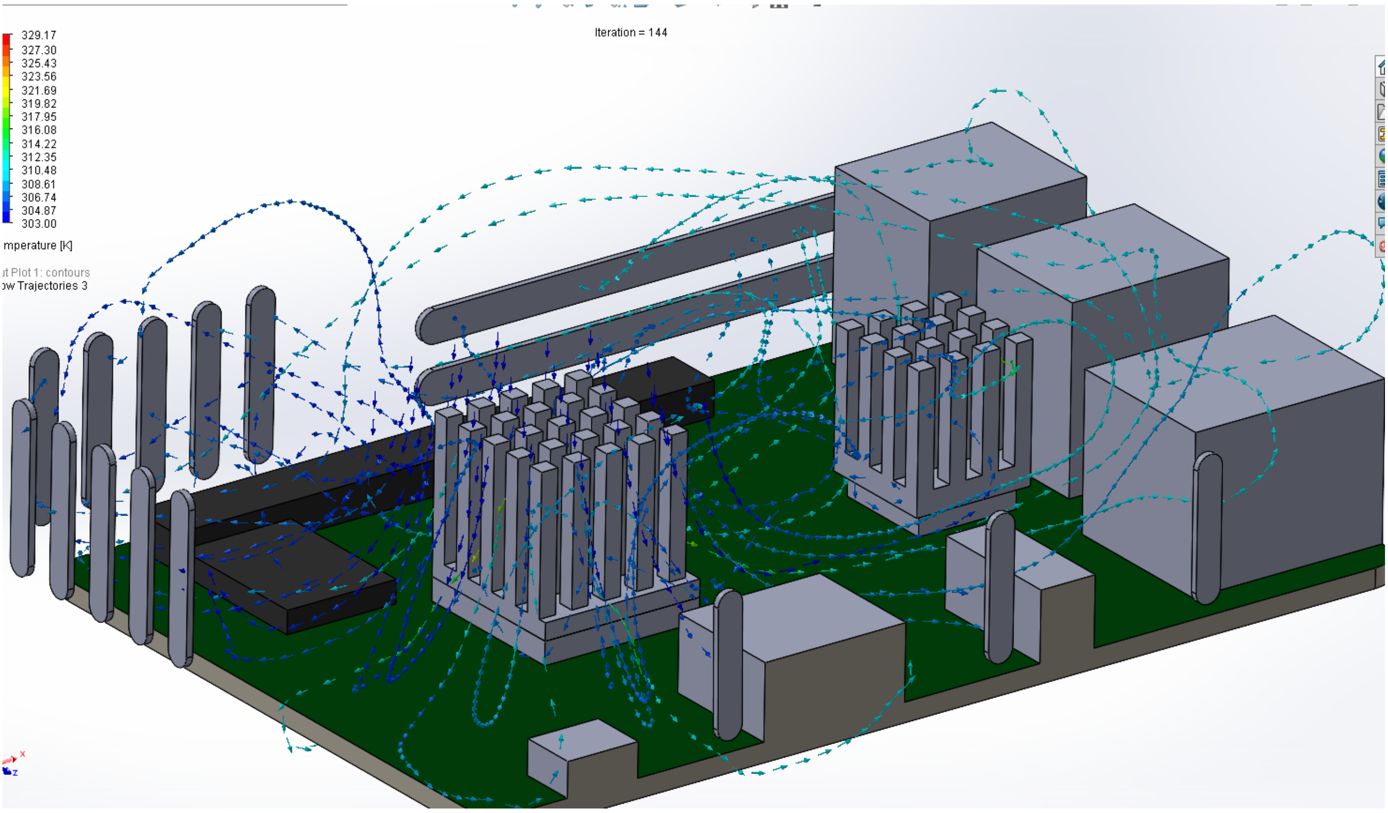


Temperature plot of chips heat sinks and glass fibre board





<u>Animated flow trajectories</u>



Double click to open animated flow trajectories video

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Observations from flow and thermal simulation

We observe that the maximum temperatures reached on the cpu and network chip are 329 kelvin(56 *C) and 319 kelvin(46 *C) respectively which is in the range specified by the manufacturer. Hence we are able to conclude that the heat sinks and fans effectively cool down the components and keep it at temperatures lower than those specified by the manufacturer.

network chip

Local Parameter	Minimum	Maximum	Average	Bulk Average	Volume [m^3]
Temperature (Solid) [K]	319.1088185	319.222566	319.1926264	319.1926264	1.62E-07

cpu

Local Parameters

Local Parameter	Minimum	Maximum	Average	Bulk Average	Volume [m^3]
Temperature (Solid) [K]	328.8526381	329.17301	329.0749538	329.0749538	4.07599E-07

Conclusion

- We have designed and performed all relevant simulations on the cad model and made changes as per the results.
- We can conclude that the design works as intended as proved in the 3 simulations we performed.
- This design was intially made to be cnc machined but with small changes it can be 3d printed as well.
- The design will be manufactured and tested once colleges reopen and i have access to college cnc machines and other labs.