Cascaded Radar Sensor Module Enclosure Design

Scope: Designing the Enclosure

Application: ADAS - Automotive 4D Imaging Radar

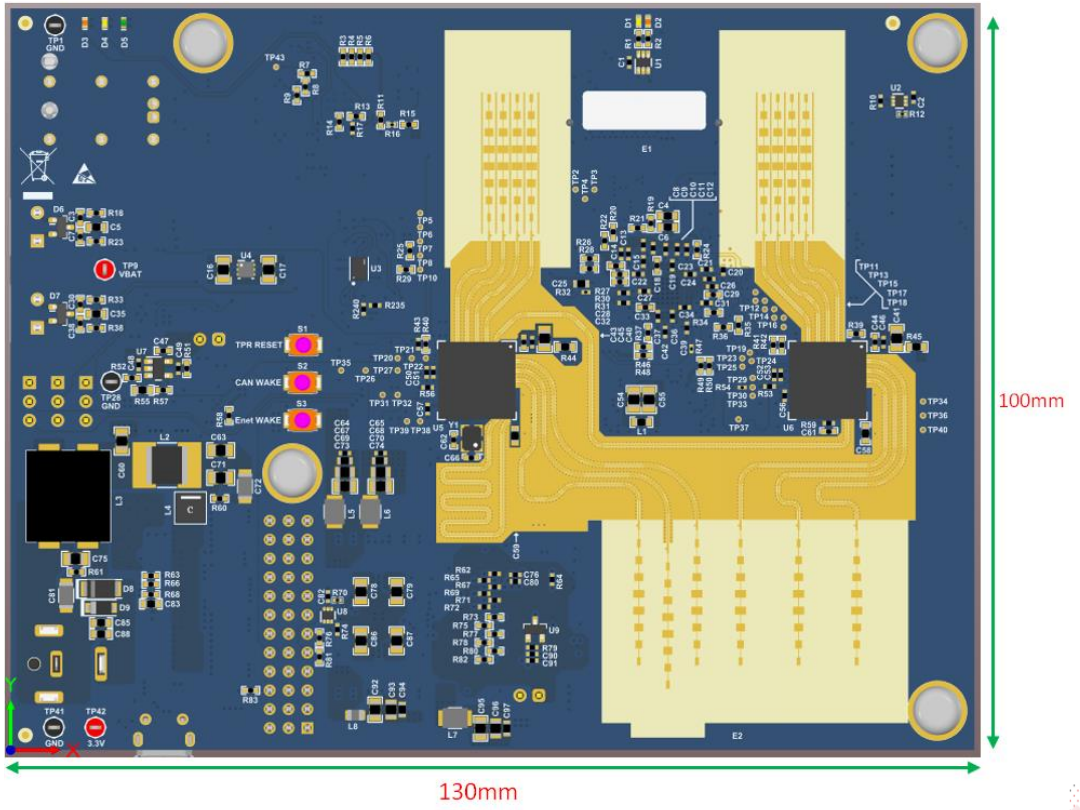
ADAS stands for Advanced Driver Assistance Systems, and it encompasses a range of technologies designed to enhance vehicle safety and improve driving experience. One specific technology within ADAS is the Automotive 4D Imaging Radar. This radar system utilizes four dimensions (3D space plus time) to provide a comprehensive and real-time understanding of the vehicle's surroundings. It plays a crucial role in enabling features such as adaptive cruise control, collision avoidance, and autonomous driving by offering precise and detailed information about the environment in and around the vehicle.

MCAD – Challenges

The client approached us with a challenging request to create a protective casing for their portable radar circuit board. The information provided posed a significant design challenge for us.

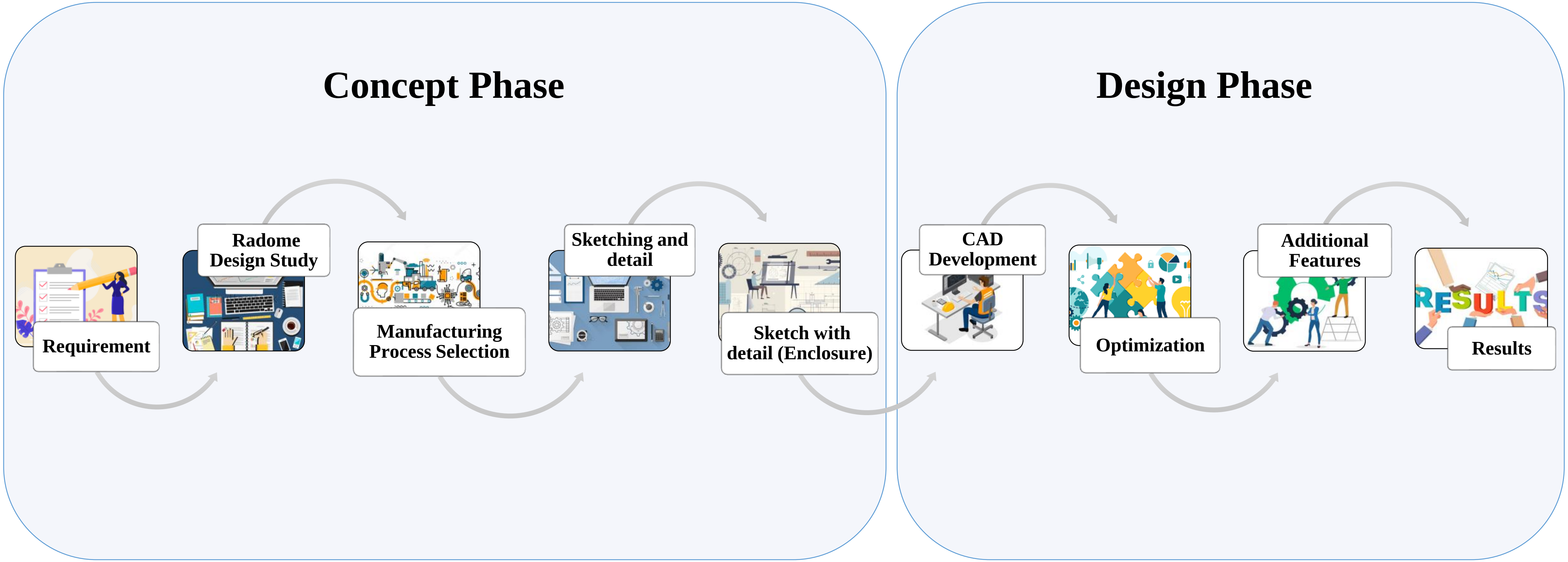
Challenges:

- Designing the enclosure should be grounded in the parameters of the radar antenna.
- Radome parameters have not been specified.
- Radome Material selection
- Contain through hole components in the PCB.



TOP VIEW

MCAD – SoW



Every stages of work have multiple brainstorming and review with the client

Concept Phase (cont.)

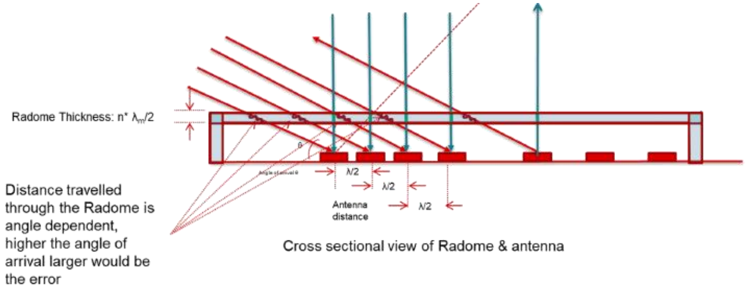
Requirement

They share info about the 3D step file for the PCB and a document contain additional details. We collect all these details and organize them in a step-by-step order.

Radar Antenna Enclosure Design Study

The condition for material selection as per the inputs are

- Enclosure material based on the radar antenna characteristics.



Cross sectional view of Radome & antenna

Material	Relative Permittivity ε_r (Measured in Infineon Lab according to [1])
Poron	1.6
Teflon (PTFE)	2
Plexi glass	2.2
Polycarbonate	2.6
ABS	2.9
Polyamide-nylon	3
HPFS glass	3.8
Gorilla glass	≈7

Following our Exploration, the enclosure design for radar antennas is influenced by these parameters

- ➢ Material selection
- ➢ Radome wall thickness
- ➢ Antenna to Radome Distance

Consideration for Radome Wall Thickness

Thickness of the Radome plays a key role in arriving at the optimum performance of the mmWave sensor. Wavelength in the Radome becomes shorter in the material than in free air. The wavelength in the material is a function of its dielectric constant. The goal is to make the wall thickness equal to the integer multiple of the wavelength in the material. This is to make sure that the Radome becomes nearly transparent for the mmWave signals.

$$t = n * \lambda_m / 2 \quad (2)$$

where:

$$\lambda_m = \frac{C}{f \times \sqrt{\varepsilon_r}} \quad (3)$$

where:

- t: thickness of Radome wall
- n: 1,2,3…
- λ_m: wavelength in Radome material
- c: speed of light
- f : mean carrier frequency used
- ε_r: relative permittivity

Material with lower Dk and Df (dielectric constant and loss tangent) are recommended. Typical materials used in Radome are Polycarbonate, Teflon® (PTFE), Polystyrene, and so forth. Typically, with Radome and Antenna, simulations are done to see there is very little degradation in the Radiation pattern.

Consideration for Antenna to Radome Distance

The optimal distance between the antenna and the Radome helps to minimize the effects of reflections caused by the Radome. These effects become minimal if the waves returned at the antenna are in phase with the transmitted waves.

$$D = n\lambda_0 / 2 \quad (4)$$

where:

- n: 1,2,3…
- D: optimal distance between Radome and Antenna
- λ_0: wavelength in air

Concept Phase (cont.)

The thickness, distance, and material selection are determined based on the given Radome parameters.

Radome wall Thickness:

$$\boldsymbol{t = \frac{n * \lambda_m}{2}}, \textbf{ where } \boldsymbol{\lambda_m = \frac{c}{f * \sqrt{\varepsilon_r}}}$$

For Polycarbonate $\varepsilon_r = 2.6$, f=80 GHz (from Client)

$$\lambda_m = \frac{3\ X\ 10^8}{80\ X\ 10^9\ X\sqrt{2.6}}$$

$$\boldsymbol{\lambda_m = 2.325\ mm}$$

So, **t= 1.1625 mm**

Antenna to Radome Distance:

$$\boldsymbol{D = \frac{n * \lambda_0}{2}}, \textbf{ where } \boldsymbol{\lambda_0 = \frac{c}{f}}$$

$$\lambda_0 = \frac{3\ X\ 10^8}{80\ X\ 10^9}$$

$$\lambda_0 = 3.75\ mm$$

D = 1.875 mm

Radome parameters :

- Material - Polycarbonate
- Radome wall thickness - 1.1625 mm
- Antenna to Radome Distance – 1.875 mm

The design of the enclosure is shaped by these specified parameters.

Manufacturing Process Selection

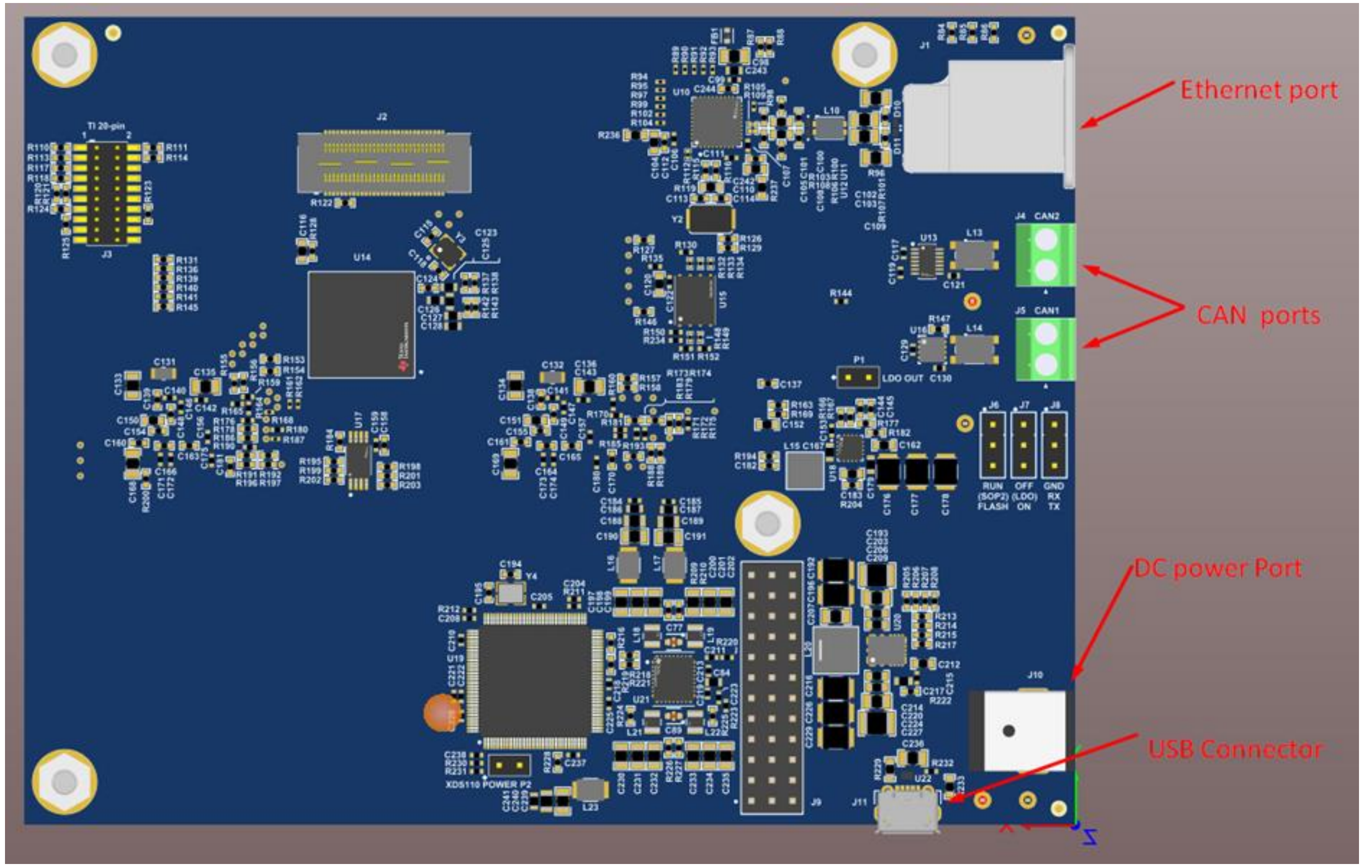
The condition for Manufacturing Process Selection as per the inputs are

- creating parts with tight tolerance
- excellent part-to-part repeatability
- Cost
- Fast cycle time

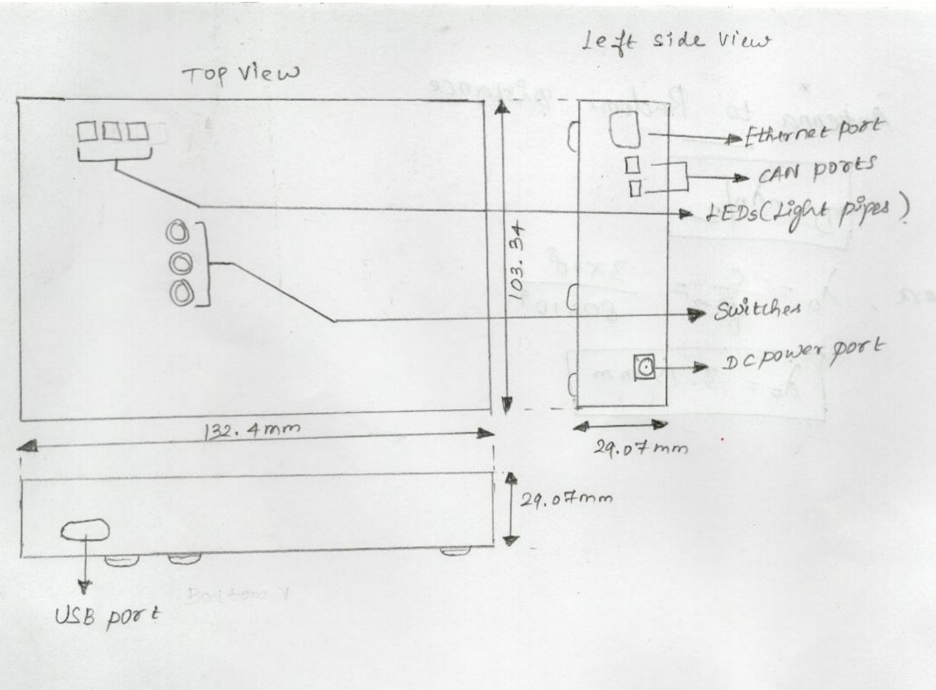
Concept Phase

Sketching and detail

Sketch with detail (Enclosure)



BOTTOM FLIPPED VIEW



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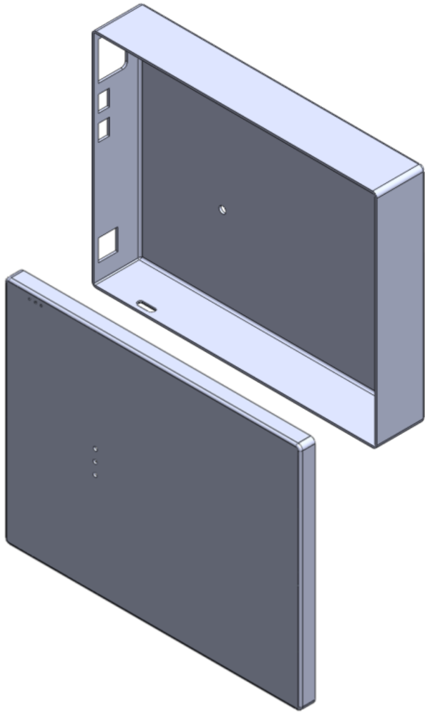
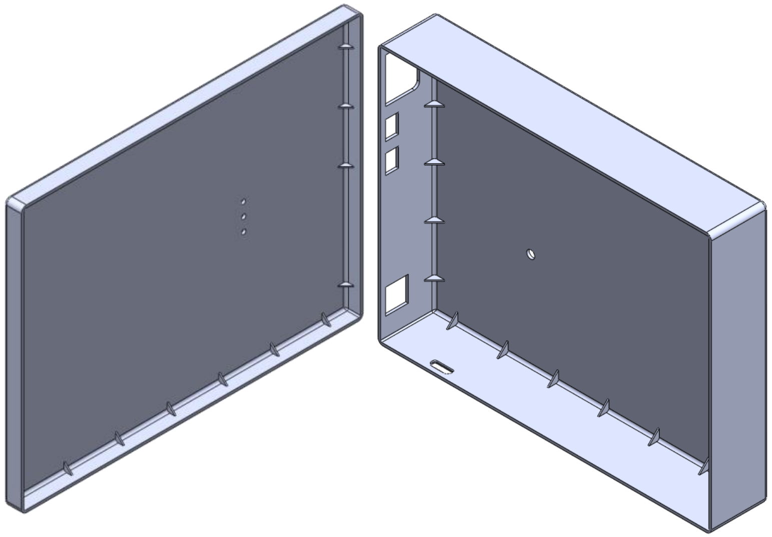
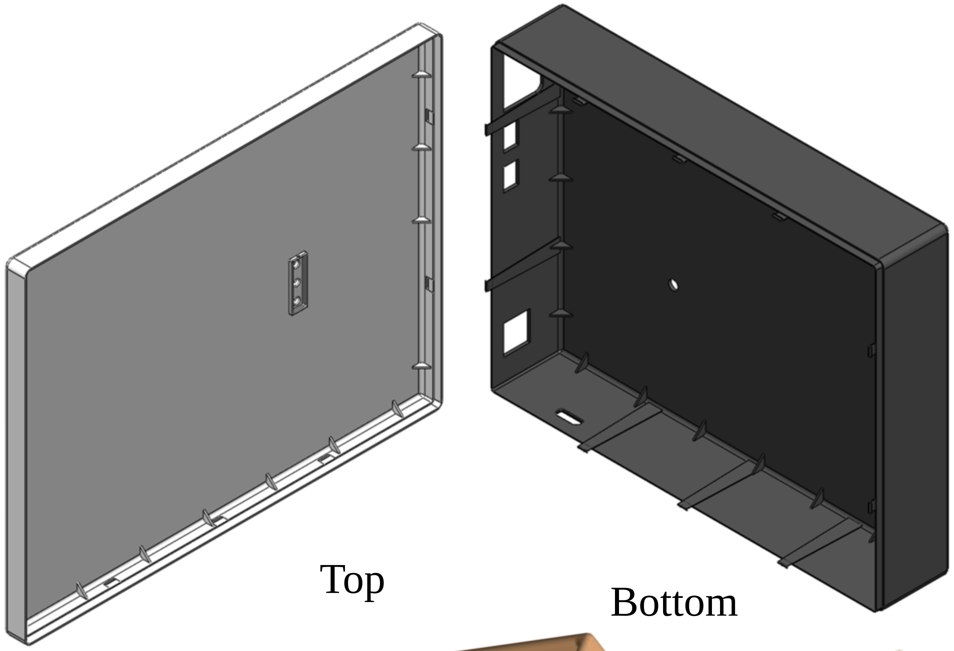
Design Phase

CAD Model development stages

Outline design → **Optimization** → **Aesthetics improvement**

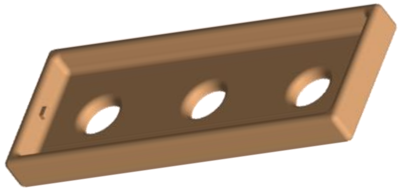




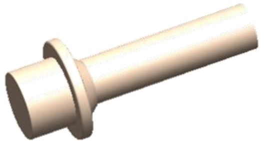


Top

Bottom



Button Holder



Button

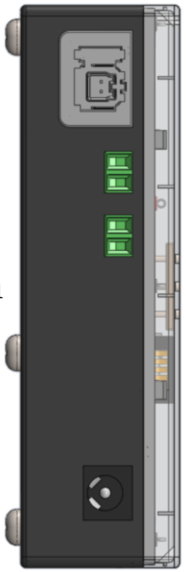
Results (cont.)

Final CAD Model

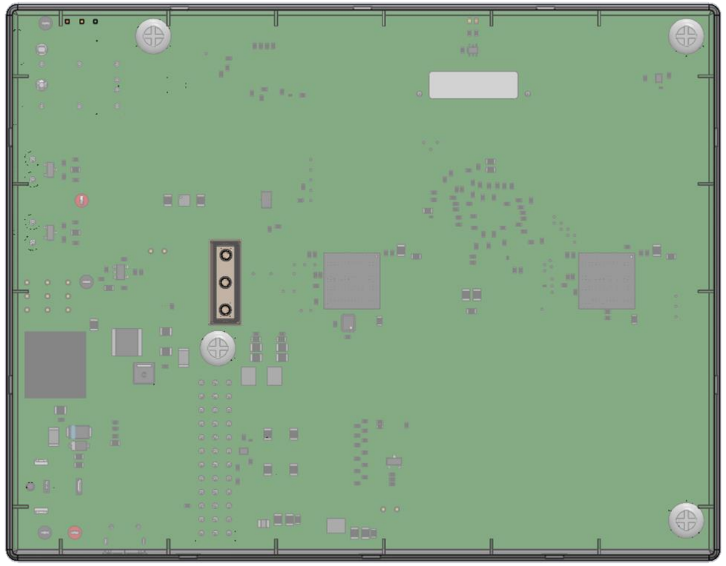
Completed design has,

Final Dimension:

132.4mm x 103.34mm x 29.07 mm



Left side View



Front View

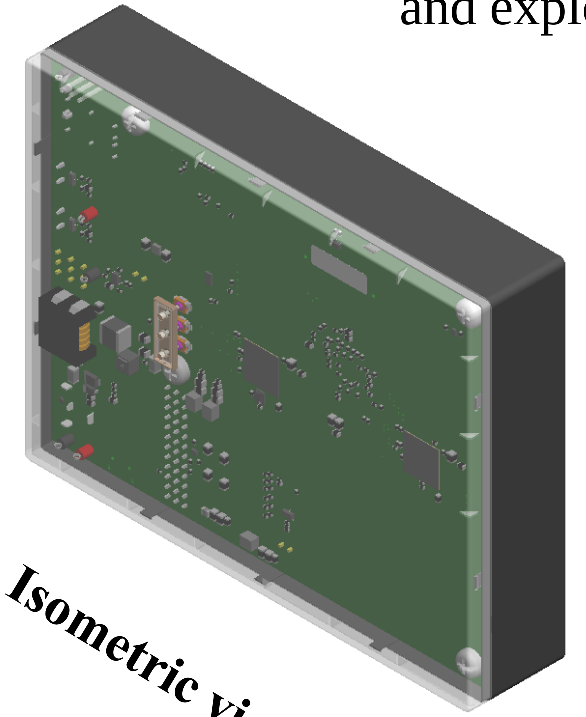
Back side View

Bottom View

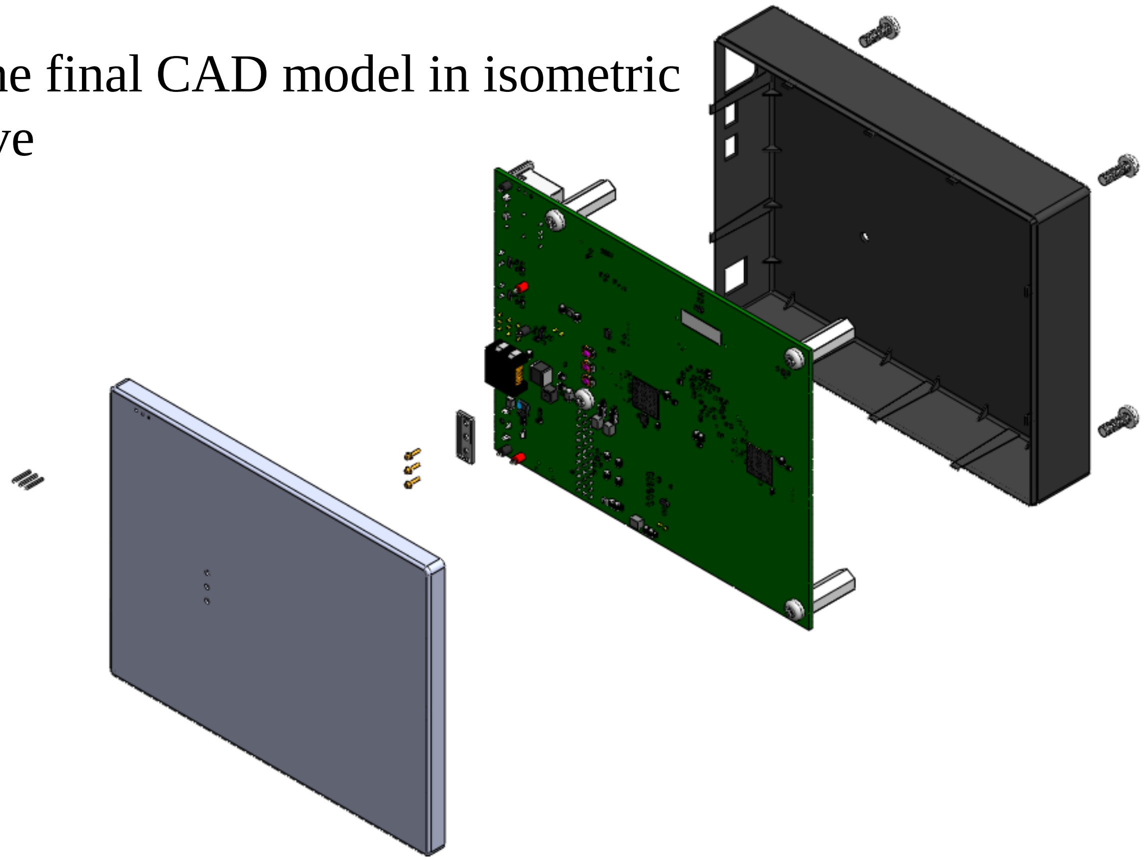
Results

Final CAD Model

Optimal reference for the final CAD model in isometric and exploded perspective



Isometric view



Exploded View

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A Heartfelt Customer’s Voice

"We're thrilled with the exceptional work from this team. Despite challenges, they expertly designed our enclosure with a creative and skillful approach in MCAD Engineering Services. Their commitment to cost-effective design without compromising quality, coupled with an efficient manufacturing process, saved us money and ensured a swift turnaround. They met our expectations in a remarkably short time, marking a significant project milestone. This team is the go-to choice for a winning blend of time, cost, and quality."

Conclusion

- We designed the enclosure, overcoming various challenges through extensive brainstorming and leveraging our expertise in MCAD Engineering Services.
- The final design was meticulously crafted to minimize interference with airwave signals and ensure high rigidity by carefully selecting materials.
- We provided a cost-effective design and streamlined manufacturing processes, saving resources and ensuring efficiency in bringing the product to market.
- Completing the design within a short timeframe marked a significant milestone in our journey, showcasing our team's dedication and capability in meeting deadlines.