Enclosure Design for Electronic Control Unit

Scope: Enclosure Design

Application: Advanced Driver Assistance System (ADAS)

Designing an enclosure for a ECU demands meticulous material selection, advanced manufacturing techniques like CNC machining or die casting, and precision surface finishing such as anodizing or powder coating for durability and aesthetic appeal. With an iterative design approach, incorporating environmental considerations and ensuring regulatory compliance, the resulting enclosure guarantees optimal protection for the ECU, the vehicular "brain," upholding the highest standards of safety and reliability crucial for automotive applications.

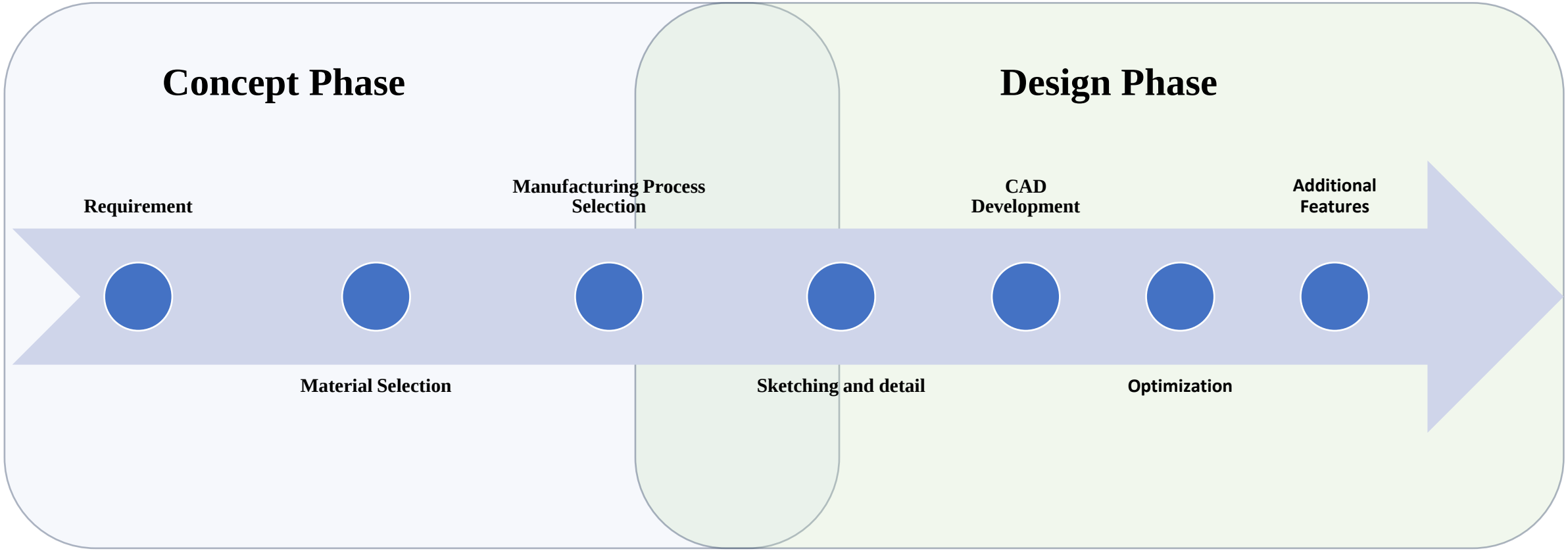
MCAD – Challenges

The client approached us with a request to design a protective case for their ECU circuit board. The information they provided, presented a significant challenge for us to work with.

Challenges:

- Material should posses high durability .
- Ensure the enclosure is sealed to protect the ECU from dust, moisture, and other environmental contaminants.
- Create opening for 2 Connector at one side.
- The board generates more heat, thus the design must efficiently dissipate it.

MCAD – SoW



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

Concept Phase (cont.)

Requirement

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

Material Selection

- Need to choose material for the enclosure that can withstand the environmental conditions (Durability) and the thermal condition.
- **Aluminum Enclosures:** Provide excellent thermal conductivity, durability, and EMI shielding. This will be Suitable for this application.

Manufacturing Process Selection

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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

Based on that, Die Casting is selected for manufacturing process.

Concept Phase

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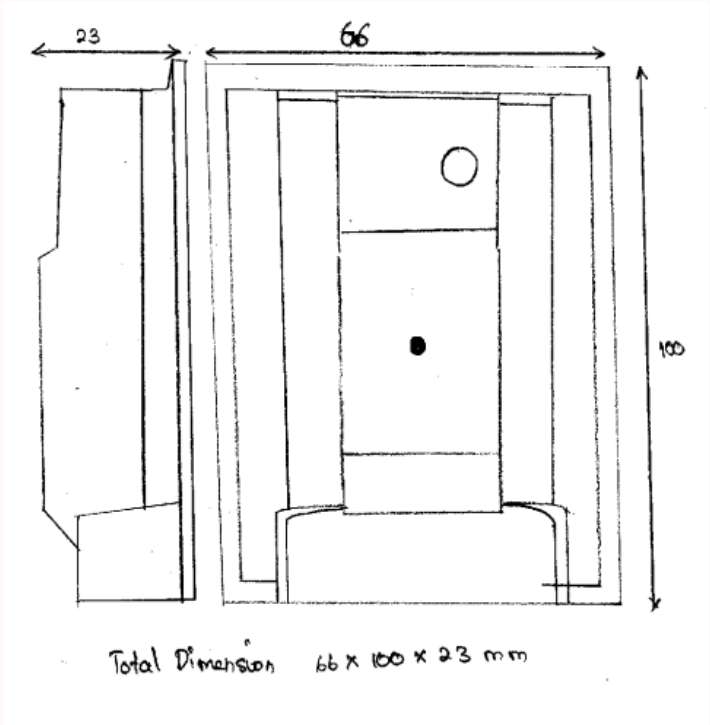
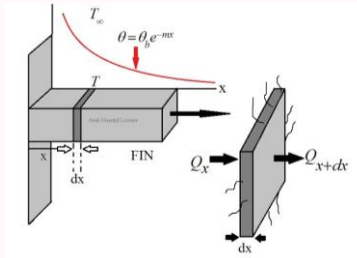
Sketching and detail

Rough Sketch with detail (Enclosure)



Fins Calculations



$$-\frac{dQ_x}{dx} = hP(T - T_\infty)$$

$$-\frac{d}{dx}\left(-KA_c\frac{dT}{dx}\right) = hP(T - T_\infty)$$

$$\frac{d^2T}{dx^2} = \frac{hP}{KA_c}(T - T_\infty)$$

Let $T - T_\infty = \theta$

$$\frac{d\theta}{dx} = \frac{dT}{dx} \text{ and } \frac{d^2\theta}{dx^2} = \frac{d^2T}{dx^2}$$

$$\frac{kA}{l} = \frac{3(0.4)}{2} = 0.6\,\frac{W}{°C}$$

$$\frac{hPl}{6} = \frac{0.1(2.8)2}{6} = 0.093\,\frac{W}{°C}$$

$$hA = 0.1(0.4) = 0.04\,\frac{W}{°C}$$

$$\frac{hPl\phi_f}{2} = \frac{0.1(2.8)(20)(2)}{2} = 5.6\,W$$

$$hA\phi_f = 0.1(0.4)(20) = 0.8\,W$$

$$Q = \frac{2\pi L(T_1 - T_b)}{\frac{\ln\left(\frac{r_c}{r_1}\right)}{k} + \frac{1}{hr_c}} \quad (1)$$

The value of critical radius r_c that is r_b for which Q is a maximum may be obtained by equating dQ/dr_b to zero.

$$\frac{dQ}{dr_c} = \frac{0 - (T_1 - T_b)\left[\frac{1}{2\pi kLr_c} - \frac{1}{2\pi hLr_c^2}\right]}{\left[\frac{k\ln\left(\frac{r_c}{r_1}\right)}{2\pi kL} + \frac{1}{2\pi hLr_c}\right]^2} \quad (2)$$

$(T_1 - T_b) \neq 0$ (Since it is the driving force)

$$\therefore \frac{1}{2\pi kLr_c} - \frac{1}{2\pi hLr_c^2} = 0$$

$$r_c = \frac{k}{h} = r_c$$

The radius at which the rate of heat transfer is maximum is known as the critical radius of insulation.

$$T(x) = \frac{q_v}{2k}L^2\left(1 - \frac{x^2}{L^2}\right) + T_{s,1}$$

$$T(0) = \frac{q_v}{2k}L^2 + T_{s,1}$$

$$T(0) = \frac{10^6\,[W.m^{-3}]}{2\,x\,2.8\,[W.m^{-1}.K^{-1}]}2.5x10^{-5}[m^{-2}] + 15\,[°C] = 19.5°C \quad (3)$$

$= k\,(dr\,rd\theta\,dz)\frac{\partial^2 t}{\partial z^2}\,d\tau$

$= k\,dV\frac{\partial^2 t}{\partial z^2}\,d\tau$ -------- (2.26)

d) Heat generated within the control volume

$= q_g\,dV\,d\tau$ -------- (2.27)

e) Rate of change of energy within the control volume

$= \rho\,dV\,c\frac{\partial t}{\partial \tau}\,d\tau$ -------- (2.28)

- According to first law of thermodynamics, the rate of change of energy within the control volume equals the total heat stored plus the heat generated. So,

$$k\,dV\left[\frac{\partial^2 t}{\partial r^2} + \frac{1}{r}\frac{\partial t}{\partial r} + \frac{1}{r^2}\frac{\partial^2 t}{\partial \theta^2} + \frac{\partial^2 t}{\partial z^2}\right]d\tau + q_g\,dV\,d\tau = \rho\,dV\,c\frac{\partial t}{\partial \tau} \text{ -------- (2.29)}$$

- Dividing both sides by dV dτ

$$k\left[\frac{\partial^2 t}{\partial r^2} + \frac{1}{r}\frac{\partial t}{\partial r} + \frac{1}{r^2}\frac{\partial^2 t}{\partial \theta^2} + \frac{\partial^2 t}{\partial z^2}\right] + q_g = \rho\,c\frac{\partial t}{\partial \tau}$$

or

$$\left[\frac{\partial^2 t}{\partial r^2} + \frac{1}{r}\frac{\partial t}{\partial r} + \frac{1}{r^2}\frac{\partial^2 t}{\partial \theta^2} + \frac{\partial^2 t}{\partial z^2}\right] + \frac{q_g}{k} = \frac{\rho\,c}{k}\frac{\partial t}{\partial \tau} = \frac{1}{a}\frac{\partial t}{\partial \tau} \text{ -------- (2.30)}$$

- which is the general heat conduction equation in cylindrical co-ordinates.
- For steady state unidirectional heat flow in the radial direction, and with no internal heat generation, equation reduces to

$$\left(\frac{\partial^2 t}{\partial r^2} + \frac{1}{r}\frac{\partial t}{\partial r}\right) = 0$$

or

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial t}{\partial r}\right) = 0$$

Since $\frac{1}{r} \neq 0$

$$\frac{\partial}{\partial r}\left(r\frac{\partial t}{\partial r}\right) = 0 \text{ or } r\frac{dt}{dr} = \text{constant} \text{ -------- (2.31)}$$

Design Phase

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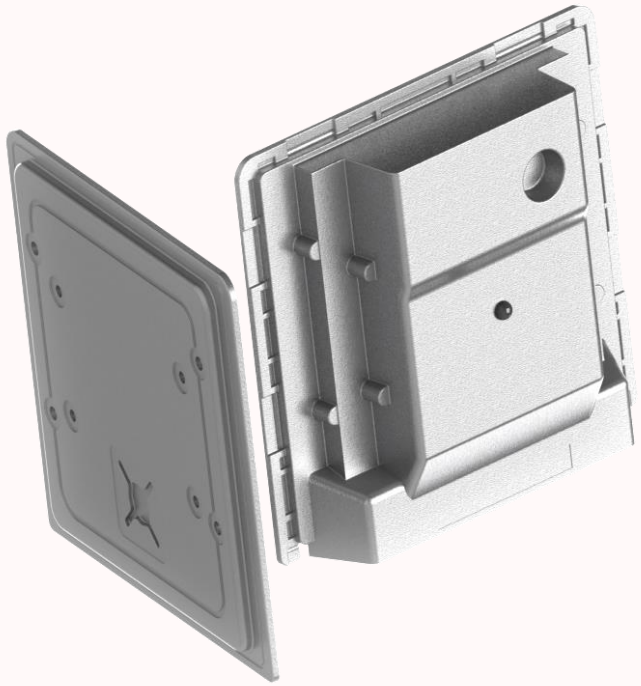
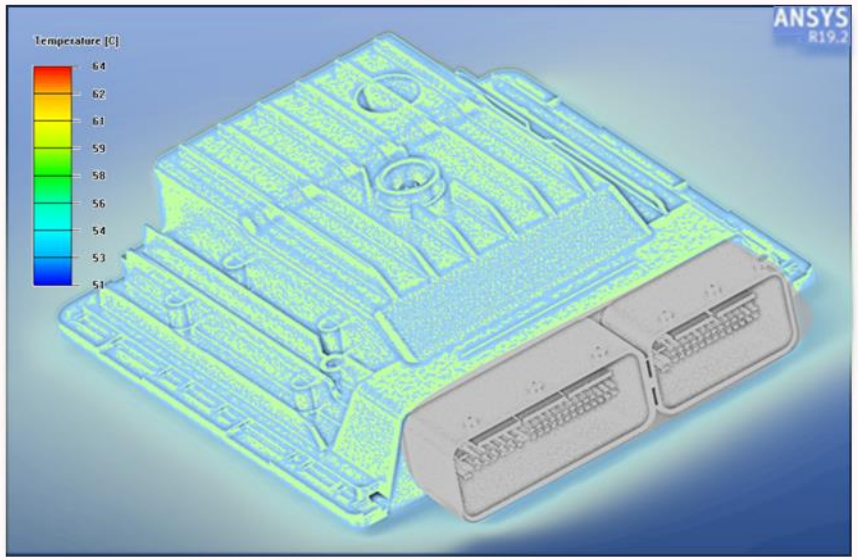
CAD Model development stages

Design Outline → **Adding Details** → **Optimizing Design** → **Thermal analysis** → **Aesthetics improvement**

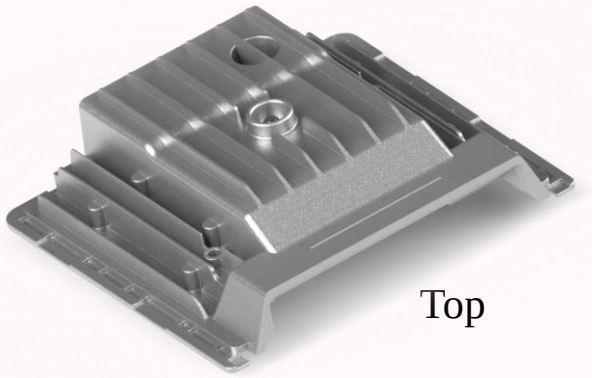




Based on the thermal analysis result, the heat transfer is optimized through efficient fin design.

Result

Final CAD Model



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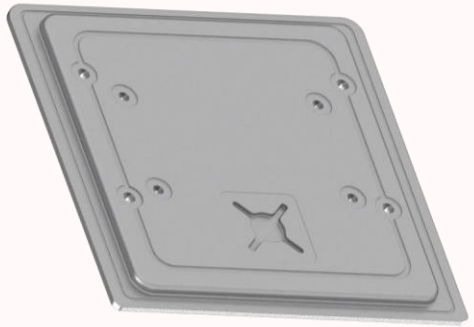

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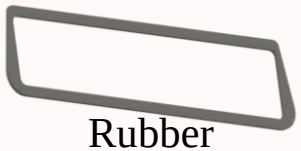
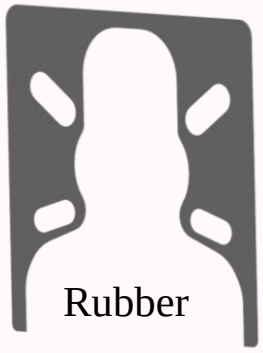


Rubber



Rubber

Final Dimension:

Without Connector – 70x100mm (Approx.)

With Connector – 70x115mm (Approx.)

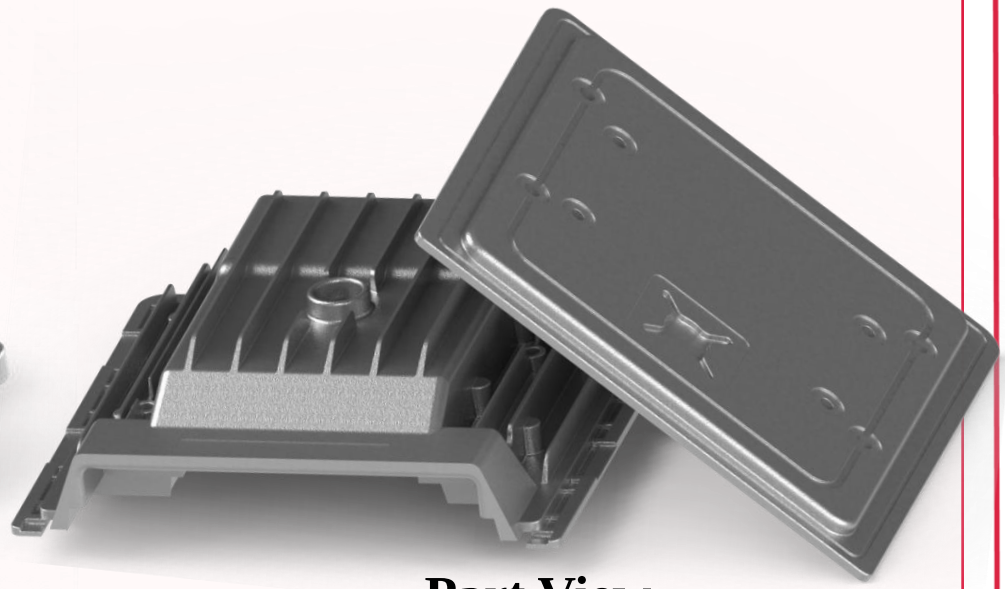
Value Add's:

The design has high heat transfer capabilities due to the optimized fin design.

Result

Final CAD Model

Isometric view



Part View

GigHz
A Global Engineering partner

An ISO-27001 ISMS Certified Company

A Heartfelt Customer's Voice

"We couldn't be more pleased with the exceptional work delivered by this outstanding team. Despite facing various challenges, they skillfully designed our enclosure with a perfect blend of creativity and expertise in MCAD Engineering Services. What truly sets them apart is their commitment to providing a cost-effective design without compromising on quality. The efficient manufacturing process they implemented not only saved us money but also ensured a swift turnaround. In a surprisingly short time frame, they not only met but exceeded our expectations, marking a significant milestone in our project. This team has proven to be the go-to choice for anyone seeking a winning combination of time, cost, and quality."

Conclusion

- In summary, Despite the challenges our team successfully designed the Enclosure after lots of brainstorming and with our expertise in MCAD Engineering Services.
- The final Design is produced with selecting material that has high durability and high thermal conductivity.
- We provided the cost effective design and the best ways to manufacturing the product.
- With completing this design in short time period, marks a significant milestone in our journey.