INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO
MESTRADO EM ENGENHARIA MECÂNICA




Design of a concept thermoplastic instrument panel for a powered two-wheeler

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julho de 2019

POLITÉCNICO
DO PORTO

Instituto Superior de Engenharia do Porto

DESIGN OF A CONCEPT THERMOPLASTIC INSTRUMENT PANEL FOR A POWERED TWO-WHEELER

2019

ISEP – School of Engineering

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POLITÉCNICO DO PORTO

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Dissertation presented to ISEP – School of Engineering to fulfill the requirements necessary to obtain a Master's degree in Mechanical Engineering, carried out under the guidance of Doctor Raul Duarte Salgueiral Gomes Campilho and Doctor Francisco José Gomes da Silva.

2019

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ACKNOWLEDGEMENTS

I would like to express the deepest appreciation to everyone involved in the development of this thesis.

To both my tutors and advisors Doctor Raul Campilho and Doctor Francisco Silva for the continuous guidance, availability and thoughtful feedback through my internship

To my tutor at Bosch Car Multimedia, João Fernandes for the intense support, patience friendship and guidance, to my manager Carsten Stoll and to the entire ECM2 team

To my integration team at Bosch Car Multimedia, Rui Almeida, Patricia Gonçalves, Márcia Sousa, Manuel Sarmento, Diogo Teixeira and Carlos Pires for their friendship and help.

To my family and friends that always showed me support.

And finally, to my girlfriend Marta, for the continuous support, care, patience, motivation and for sharing this experience with me. To her, my deepest appreciation for everything.

KEYWORDS

Powered two-wheeler (PTW); Instrument panel; Cluster; Product development; Thermoplastic; Injection moulding; Heat bending, Adhesive bonding.

ABSTRACT

This work has centered on the development of a new concept of instrument panel to use in a powered two-wheeler.

New concepts enter the automotive and transportation market at a very high rate. One of the most recent developed technologies is the replacement of rear view mirrors for cameras, which transmit their information to LCDs places inside the vehicles cockpit. This brings advantages regarding vehicle efficiency, aesthetics and safety. By replacing the mirrors, we can reduce the frontal area of a vehicle, which will reduce drag when travelling at speed. This will promote the energetic efficiency of the vehicle, which is one of the main objectives in the industry. On the other side, by replacing the mirrors with cameras we can offer a spreader view and adapt the captured image to the external light, improving the visual information that is presented to the user.

This way, the objective of this study is to adapt this concept to a powered two-wheeler.

PALAVRAS CHAVE

Motociclo motorizado; Painel de instrumentos; *Cluster*; Desenvolvimento de produto; Termoplástico; Injeção; Dobragem a quente; Ligação adesiva.

RESUMO

Este trabalho centrou-se no desenvolvimento de um novo conceito de painel de instrumentos para utilizar num motociclo motorizado.

Cada vez mais, novos conceitos tecnológicos dão a sua entrada no mercado dos transportes. Uma das mais recentes tecnologias desenvolvidas é a substituição dos espelhos retrovisores por câmaras que transmitem a sua informação para LCDs, estes por sua vez encontram-se dentro do cockpit. Isto é vantajoso ao nível de eficiência do veículo, estética e segurança. Ao remover os espelhos, conseguimos reduzir a área frontal de um veículo, o que por sua vez irá diminuir o atrito com o ar quando em circulação. Isto promove o aumento da eficiência energética do mesmo, o que é um dos principais objectivos na industria dos transportes. Por outro lado, ao substituir os espelhos por câmaras conseguimos também oferecer maior amplitude de visão e adaptar a imagem captada de acordo com a luz exterior, melhorando assim a informação que chega ao condutor.

Deste modo, o objectivo deste estudo é adaptar este conceito a um motociclo urbano.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

3D	Three-dimensional
ABS	Acrylonitrile butadiene styrene
ASEAN	Association of Southeast Asian Nations
CAD	Computer aided design
CAE	Computer-aided engineering
CAGR	Compound annual growth rate
CAM	Computer-aided manufacturing
CATIA V5	Computer-aided three-dimensional interactive application version 5
CNC	Computer numerical control
CO_2	Carbon dioxide
DFA	Design for assembly
DFC	Design for cost
DFD	Design for disassemble
DFE	Design for environment
DFM	Design for manufacturing
DFR	Design for recyclability
DFX	Design for excellence
DNA	Deoxyribonucleic acid
ECU	Engine control unit
ESC	Electronic stability control
ESP	Electronic stability programme

FFC	Flexible flat cable
HMI	Human-machine interface
ISO	International Organization for Standardization
LCD	Liquid crystal display
LED	Light emitting diode
MATIS	Material information system
MCU	Microcontroller
MEMS	Microelectromechanical systems
NO_X	Nitrogen dioxide
OECD	Organisation for Economic Co-operation and Development
PBT	Polybutylene terephthalate
PC	Polycarbonate
PCB	Printed circuit board
PET	Polyethylene terephthalate
PLA	Polylactic acid
PLM	Product lifecycle management
PMMA	Polymethyl methacrylate
PP	Polypropylene
PPE	Polyphenylene Ether
PPS	Polyphenylene sulphide
PTFE	Polytetrafluoroethylene
PTW	Powered two-wheeler
RP	Rapid prototyping

SO_X	Sulphur oxide
TD20	20 % talc filled
TFT	Thin-film transistor
UV	Ultraviolet
V2V	Vehicle-to-vehicle
VAG	Volkswagen AG

List of units

%	Percentage
€	Euro
°	Degree
°C	Degrees Celsius
bar	Bar
bn	Billions
C_d	Drag coefficient
cm	Centimetre
g	Gram
h	Hours
HRC	Rockwell hardness C scale
in	Inches
kJ	Kilojoule
km	Kilometre
m	Meter

Min	Minute
mm	Millimetres
MPa	Megapascal
rpm	Revolutions per minute
Ton	Tonne
US$	United States dollar

List of symbols

∑	Summation
Am	Frontal surface area of one mirror
At	Total frontal surface area
Awm	Total surface area without mirrors
D	Diameter
FR-4	Grade 4 flame retardant
L	Length

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INTRODUCTION

1 INTRODUCTION

This first chapter presents the framework, objectives and layout of this project, as well as Bosch Car Multimedia S.A, where the internship took place.

1.1 Framework

Currently, powered two wheelers (PTWs) are on the rise, with major cities and countries getting so highly populated, people are redirecting their transportation duties into PTWs. This happens, because PTWs provide an escape to traffic congestions, easier accesses to parking and are cheaper to purchase and to maintain. With such relevant advantages as a daily transport, it is easy to see how the market continues to increase. Both automotive and PTW manufacturers have in their interest to continuously improve the overall vehicle efficiency, safety and technology when launching new products. Another big factor in the current transportation market is the environmental impact that the vehicle will have. A new technology that is starting to be introduced in trucks and consumers cars as a way to achieve better fuel economy, efficiency and safety, is the replacement of conventional side mirrors for cameras. Thus, removing the mirror assembly and reducing the frontal area and drag coefficient (C_d) of the vehicle.

The internship took place in the team CM/CI2-ECM2 that operates in the development department at Bosch Car Multimedia in Braga. This team is responsible for different projects, both in the two-wheeler and automotive areas, in which instrument panels for VW, Audi, Rolls-Royce, Kawasaki and Ducati are developed.

For this project, there was not a specific customer, and it was developed as a study for a future application in the PTW market.

1.2 Objectives

The main objective of this project was to successfully develop an instrument panel that could be installed in a large array of PTWs, and this product shall be able to implement the rear view camera technology as an option to regular mirrors.

In order to do this study, the following tasks were performed:

- Market research;
- Study current products and methodologies used in the company;
- Define the product scope;

- Conceptualization of the instrument panel design;
- Mechanical concept;
- Computer-aided design (CAD) model of the instrument panel;
- Technical drawings;
- Material selection;
- Manufacturing processes to use.

1.3 Thesis Layout

In addition to this chapter, the thesis comprehends four more chapters:

- Chapter 2: Literature review. This chapter introduces every relevant topic to the development of the product;
- Chapter 3: Concept and development of the instrument panel. This chapter defines the materials and manufacturing processes. The technical drawings, assembly process and mechanical concept are presented. 3D print the assembly in order to visualize the final product.
- Chapter 4: Conclusion. This chapter resumes the motivation, development and final product achieved during the internship report.
- Attachments: Relevant documents that were used in the research and development of the thesis.

1.4 Company presentation

The Bosch Group was founded in 1886, when Robert Bosch opened the "Workshop for Precision Mechanics and Electrical Engineering" in Stuttgart, Germany. Since 1964, Bosch as been divided by three main shareholders: Robert Bosch Stiftung GmbH, the Bosch family and Robert Bosch GmbH (Figure 1).

Figure 1 - Bosch shareholders (Bosch Global, 2019)

The Bosch company is a global company that employs around 409900 associates worldwide (December 31, 2018), and it is divided into four main business sectors. These are: Mobility Solutions, Industrial Technology, Consumer Goods and Energy and Building Technology. In 2018 total worldwide sales represented €78.5 billions (bn) (Figure 2).

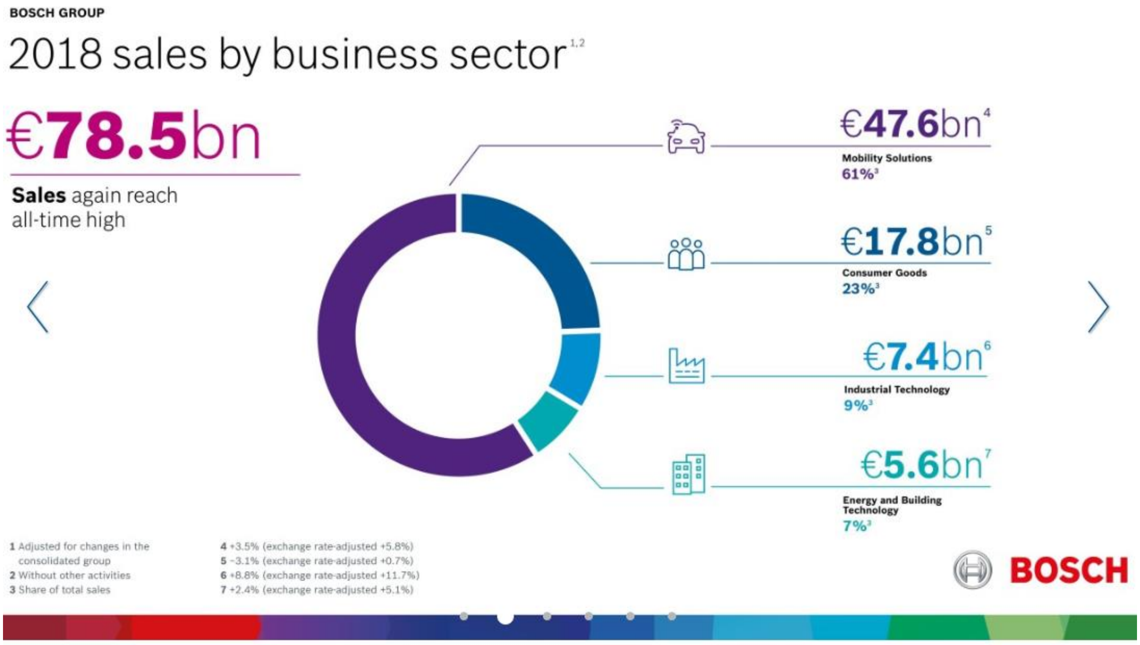

Figure 2- Bosch Group sales by business sector in 2018 (Bosch Global, 2019)

The Bosch Group slogan "Technik furs leben", which means "Technology for life", represents the company's ideology of delivering innovation and connectivity, in order to improve people's life quality, spark enthusiasm and to preserve natural resources (Bosch Comany, 2019).

In Portugal, the Bosch Group has five different locations, divided by three different business areas:

- Bosch Car Multimedia;
- Bosch *Termotecnologia*;
- Bosch Security Systems.

Bosch Car Multimedia is located in Braga and it was opened in 1990. It features the largest plant of any of the Car Multimedia section, therefore it has had several recent investments and now counts with a very important development centre.

BIBLIOGRAPHIC WORK

2 THEORETICAL BACKGROUND

2.1 Component fabrication in the powered two-wheeler sector

2.1.1 Importance of the powered two-wheeler sector in the global economy

A powered two-wheeler (PTW), also known as a motorcycle or motorbike, is a two-wheeled vehicle, primarily driven by an internal combustion engine or an electrical motor. There are two main types of two-wheelers, motorcycles and scooters. They are both constituted by metallic or fibrous bodies, being that the main difference is that scooters have footboards on which riders can rest their feet while driving.

The global motorcycles market is estimated to be valued at US$ 115,720.5 million by the end of 2018 and reach US$ 156,903.0 million by the end of 2026, with a compound annual growth rate (CAGR) of 3.9% over the forecast period. Therefore, the global motorcycles market is anticipated to represent an incremental opportunity of US$ 41,182.58 million between 2018 and 2026 (Motorcycle Market, 2018).

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The PTW sector ended 2018 with the third highest sales level ever, at 61.9 million units, which represent an increase of 1.8% from the previous year. The current record was obtained in 2014 when total units sold were 67.4 million. The market is highly influenced by India, with 21.5 million sales (+8.5% from previous year); China, with 15.5 million units (-9.3% from previous year); Indonesia, with 6.38 million units (+8.4% from previous years), Vietnam, with 3.39 million units (+3.5% from previous year); Pakistan, with 1.9 million units (+6.6% from previous year); amongst others (Motorcycle Market, 2018).

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The increase in demand on the PTW market is believed to be related with the increase of middle-class population across the globe, which see a great opportunity to have a very affordable and practical mean of transportation.

Currently, manufacturers are focusing on manufacturing conventional motorcycles with a sportier design, since these are popular among younger riders and consumers in general. Economy segment motorcycles have maintained their prominence in the motorcycle market. The main improvements have been focused on increasing efficiency, range, longevity, and lowering maintenance costs, which make this type of transportation very appealing. The evolution of these features are expected to further enhance the demand of PTW’s worldwide, therefore augmenting the market share in the near future. Other evolution in the motorcycle market that has been paved the way by the automotive industry is the use of electric motors as power plants. These alternatives are more efficient, cheaper to run and cleaner for the environment with the main downside being the absence of noise. Actually, this can be dangerous since other transports or pedestrians may not notice the PTW users on the road (Motorcycle Market, 2018).

2.1.1.1 Global Motorcycles Market Analysis by Product Type

PTW's can be divided in motorcycle and scooter segments, it is expected that motorcycles will approximately account for a 67.1% volume share and scooters 32.9% volume share in the global motorcycles market by the end of 2026, which means that is expected that motorcycles will suffer a CAGR of 3.6% over the forecast period (Motorcycle Market, 2018).

2.1.1.2 Global Motorcycles Market Analysis by Technology

Combustion engine motorcycles currently represent the majority of sales in the PTW market. However, it is expected that the electric motorcycle segment will grow with a significant rate over the forecast period (2019-2026), since a CAGR of 4.9% is expected (Motorcycle Market, 2018).

2.1.1.3 Global Motorcycles Market Analysis by Region

The country that is the biggest contributor to the PTW market is India, which represented approximately 37.9% of the market volume share in 2018. India has an anticipated volume CAGR of 4.2% over the forecast period, which translates into an expected sales revenue of US$ 57,819.3 million by the end of 2026. Market growth in Association of Southeast Asian Nations (ASEAN) countries is expected to remain higher when compared to the global average between 2018 and 2026, making them the biggest contributors for the PTW market (Motorcycle Market, 2018).

2.1.2 Importance of the powered two-wheeler sector in the local economy

In Portugal, the PTW sector is growing by the year. In 2017, motorcycle sales increased by 24.7% when compared to 2016. In the local market, PTW's between 50 and 125 cm^3 represented 52% of all motorcycle sales with 14.514 total units sold. The second most relevant segment, consisted of the motorcycles with displacement's above 125 cm^3, which represented 37% of sale with 10.299 units, sold. Finally, in the PTW's with 50 cm^3 or less, sales represented 11% with 3.091 units sold (Moto, 2018). In 2018, the same pattern maintained and the market continued to grow. When compared to 2017, sales increased 9.6%, with 31.994 total units sold (Portal, 2019).

2.1.3 Fabrication processes

As in other business areas, the fabrication process in the motorcycle market follows simple steps: conceptualization, design, development, testing, production and release, in which the first four steps may repeat themselves, providing evolution and better results at each iteration. The first step is to analyse customer requirements and conceptualize the idea behind the product. Then, a computer aided design (CAD) part that fulfils the requirements is designed and developed. Software based tests are made, followed by real world ones. The obtained results are then used to refine and improve the performance and specifications of the product. When the acceptance criteria are fulfilled, the product is ready for manufacture, therefore the production begins. Raw materials, parts and components usually arrive from suppliers to other manufacturing plants, which in turn may also supply others along the line. At each plant, the products get closer to the final product, meaning that at the final plant, several components converge from different suppliers and the final assembly is completed. Materials and components are mostly transported on a daily basis by truck or rail, although ships and airplanes can be also utilized (Figure 3).

Figure 3 - Convergence of parts from different suppliers to manufacture a Porsche Cayman 718 (Clark, 2019)

2.2 Materials used in the component fabrication

PTW's have several components made from different materials. Primary raw materials utilized are metals, plastics, rubbers and composites, depending on the application. The frame is composed almost completely of metals and alloys such as aluminium or steel, as are the wheels, although the frame may occasionally be overlaid with plastic. Tires and handgrips are made of rubber, while the seat is usually made from foams and synthetic materials, such as polyurethane. The PTW brake system, suspension and powertrain: engine, gearbox, pulleys, chains, amongst others, are usually made from iron, aluminium and steel alloys or even carbon-fibre composites. The electrical system, battery, wiring and coils are mostly made from plastics and metals, while the control panel and lights are usually made by plastics and composites. In the cluster fabrication industry, most components are made of composites, polymers and metals depending on the application (Palm, 2019). The approximate percentage of use of each material in the automotive sector is presented in Figure 4 (Hovorun T. P., 2017).

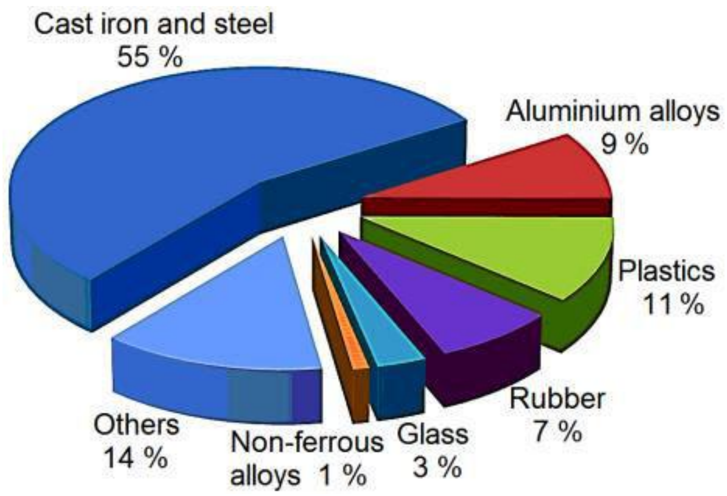


Figure 4 - Materials used in the automotive industry (Hovorun T. P., 2017)

Metals and alloys, such as steel, aluminium, iron, magnesium and titanium are supplied in ingot, tubular or sheet formats. The main processes utilized in the motorcycle industry to shape these materials are injection, stamping, casting, machining, forging, amongst others.

For example, crankshafts, which are mostly manufactured from steel, can be produced from three traditional methods: forging, casting and machining (Pawar, 2015). Each process will have its benefits and its downsides, influencing even the performance and specifications of the final product, For example, when comparing forged and casted components, although forged ones will be more expensive they will also be far stronger (Figure 5) (McGann, 2015).

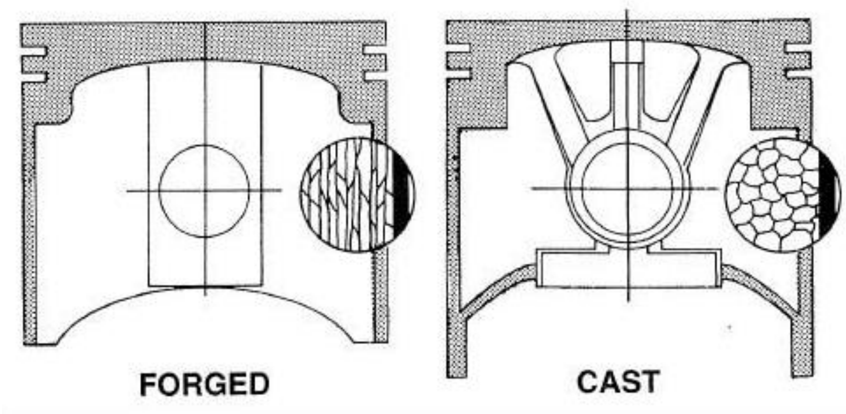


Figure 5 - Forged vs. casted internal combustion engine pistons (McGann, 2015)

Thermoplastics such as polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polypropylene (PP), polymethyl methacrylate (PMMA), polybutylene terephthalate (PBT), Polyphenylene Ether (PPE), are mostly made by injection moulding (Park H. S., 2014), although they can also be processed by extrusion, lamination, pultrusion, laser cutting, stamping, amongst others, depending on the application. Plastic components, such as motorcycle fenders and panels, can be produced by injection, which is a process with high efficiency and manufacturability, in which the material is heated and forced through a cavity into a mould originating the final component (Spina, 2004).

Synthetic and natural rubbers are mostly processed by injection or extrusion. Components like tires, which are utilized in every PTW on the market, are produced by extrusion, followed by a cure and vulcanization (Arvind Boudha, 2011).

2.2.1 Typical material requirements

The personal transportation industry is one of the largest consumers of construction materials in the world. Materials are being required to be more durable and reliable, in order to easily sustain forces and mechanical loads without affecting vehicle integrity. Materials should also be lightweight, in order to improve the handling characteristics of the vehicle while using less powerful and more efficient engines. Weight reduction will also have positive effects on lowering the vehicle’s inertia, which will require less energy from the braking systems and puts less stress on the chassis and suspension components. Corrosion resistance is also very important since vehicles will be used outdoors and can be in constant contact with corrosive-aggressive environments, thus components should be resistant to this phenomenon, which may cause performance and visual defects. In order to be competitive, materials should have the lowest cost possible and should provide easy manufacturability. The easier and faster a material can be processed, the more competitive and attractive it will be. A material that is hard to process will be more expensive and less efficient to work with. There is also a great value in the recyclability and emissions of a material. Currently, these issues have a bigger impact on the material choice than ever before. Therefore, they are very important when it comes to material selection. The less pollutant options will have great benefits when it comes to overall emissions, therefore being preferred over materials with higher emissions. It is also preferred to have a material that can be reused and recycled, since they will be more ecological and will promote a more sustainable environment (Hovorun T., 2017).

2.3 Evolution of the fabrication processes

Both materials and fabrication processes are in constant evolution in order to achieve a higher net energy productivity and to enable rapid manufacture of energy-efficient, high-quality products at competitive cost. With environmental concerns increasing at a very high rate, it is very important that the industry is able to achieve a sustainable manufacturing. Reducing process steps, materials usage, or part counts will reduce the energy embedded in the manufacturing value chain, thus decreasing the use of raw materials. The same applies for technologies that enable the manufacture of materials and components that increase recyclability. New software features help immensely in this topic. In fact, initial product conceptualization and design could enable the selection of a manufacturing process to meet specific costs, times, energy intensities, and life-cycle energy consumption requirements. There has been evolution in several fields, such as high-temperature processing, waste heat minimization and recovery, and overall sustainable manufacturing (U.S. Departement of Energy, 2017).

For example, in the metal processing industry, gas-fired furnaces, which have poor thermal efficiency (from 20-45%) are substituted by higher thermal efficiency alternatives such as electrical resistance heaters (efficiency up to 99%). This happens because electric resistance furnaces use a continuous-flow system in which there are melting and holding furnaces, therefore allowing a higher efficiency. Other benefits include the reduction of on-site emissions of carbon dioxide (CO_2), sulphur oxide (SO_x), nitrogen oxide (NO_x) and particulates (U.S. Department of Energy, 2011)

Stamping, used to produce car panels, representing about 25% of an entire vehicle, includes drawing, piercing, trimming, and flanging operations that will heavily rely in metal-to-metal contact. This process utilizes two-sided tooling and is becoming harder to apply, since the metals being formed are increasing in strength and hardness. This process can be substituted by electrohydraulic forming, which utilizes high voltage electrical discharges to create the panels. This process is extremely fast, uses cheaper and simpler single-sided tooling, improves formability for both advanced high strength steels and aluminium alloys, improves the trimmed surface quality and eliminates the springback effect of the stamped part. Ultimately it will also reduce energy use and carbon emissions, which is nowadays a highly sought requirement in the industry (U.S. Department of Energy, 2011).

Waste heat has no real economic or environmental benefits, although if it were to be recovered and reused, it could have a positive impact on economic health, energy consumption and carbon emissions. Therefore, recovering waste heat and converting into energy is also a great way to be more sustainable, flowing gases and vapours from sources such as industrial machines and engines can be routed across turbines or extraction devices in order to produce energy. The flowing gases will create shaft power that can be turned into electrical power through a generator, meaning that it is possible to produce energy from otherwise wasted gases and heat (U.S. Departement of Energy, 2017).

2.4 Product development

2.4.1 3D modelling

Three-dimensional (3D) modelling is a mathematical representation of any surface of any object in three dimensions in a specific software. The final product can be rendered into a two-dimensional image, used in physical simulations or even physically created through computer numerical control (CNC) machines or 3D printing devices (Khemani, 2009). 3D models represent a physical body using a collection of points connected by various geometric entities, and applications range from engineering solutions to scientific research, such as numerical simulations, rapid prototyping, computational fluid dynamics, visualization, amongst others (Jianwei Guoa, 2019). These models can be created by hand, with algorithms, or scanned, with possible further definition by texture mapping, which will allow a very high-quality simulation of the real component. 3D models can be divided in two main categories, solids and surfaces. Solids define the volume of the object that they represent, while surfaces represent the boundary of the object (at an infinitesimally low scale). 3D software can be used to perceive how the final product or assembly will look like, either from a designer or a mechanical point of view (Khemani, 2009). To get a further perspective on how the object will look like, it is also possible to render it in a photorealistic way (figure 3). A render is a high-quality image generated from a 2D or 3D model. This image contains a chosen viewpoint, texture, lighting and shadowing, mimicking a non-virtual representation of the object being rendered. These can vary from simple structure objects to more intricate ones, like human faces, limbs and complex mechanical components (Figure 6) and even fluids (Xi-Dao Luan, 2008).

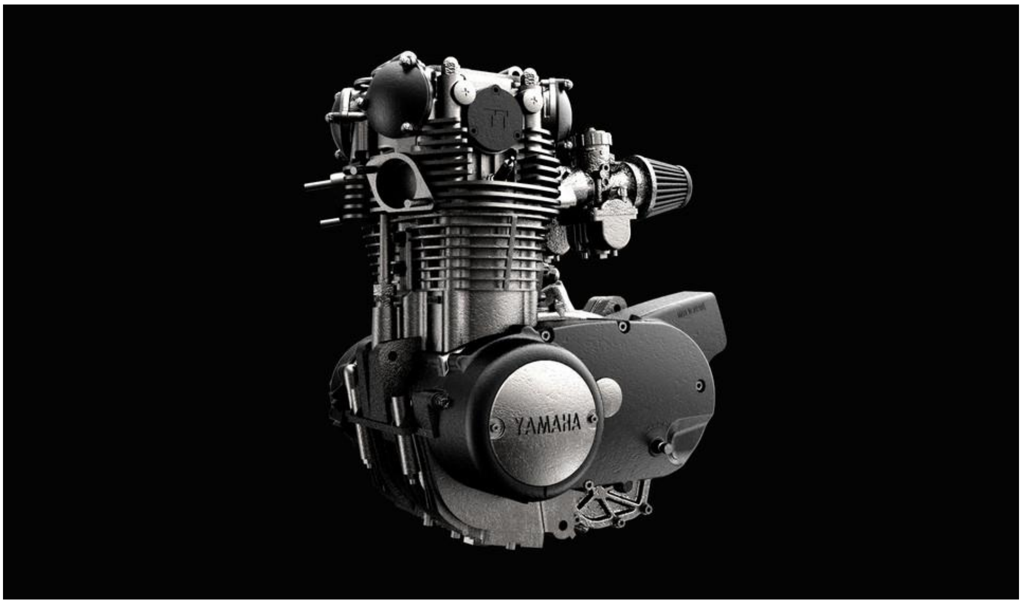


Figure 6 - Yamaha xs650 engine render (Miguel, 2017)

2.4.2 Benchmark tests

When developing mechanical components, it is very important to test them accordingly. If a component will be used for a specific job, then the tests it will have to successfully pass will be similar to the type of interactions it will suffer in its life cycle. There are countless physical and chemical tests, yet the most notorious ones are compression tests, hardness tests, crash tests, tensile tests, fatigue behaviour, vibration behaviour, corrosion resistance, turbulent flow (when the component will interact with a fluid), load capacity analysis, amongst others (Ulm-Sawade, 2018). Every benchmark test applied will be based on essential technical standards and guidelines, such as ISO (the most prominent organization), DIN, EN, ASME, ANSI, in order to have comparable results and uniformity, which will allow worldwide acceptance and application of a product or material (Abbott, 2005).

Figure 7 - International Organization for Standardization (ISO) logo (McDubus, 2015)

For example, rocket boosters and spacecraft's, which are subjected to intense acoustic environments during launch, are tested with vibration, vibro-acoustics, modal characteristics (such as natural frequencies, damping ratios and mode shapes), sound transmission loss, and shock tests, since these components will suffer from high levels of vibration in structural components (National Aeronautics and Space Administration, 2011).

With the increased interest in producing lighter vehicles to increase performance and fuel efficiency, manufacturers have increased the use of aluminium alloys over mild steel by over 80% between 1995 and 2000, thanks to its higher strength-to-weight ratio. Since a vehicle needs to offer protection to its occupants, the crash behaviour must be considered when choosing a material. Therefore, a split tensile strength test is executed to identify the constitutive response and damage evolution in different alloys at high strain rates (Smerd, 2005).

In a wide field of applications, such as automobiles, PTW's, aircrafts, bridges, satellites, amongst others, honeycomb structure solutions are employed. These are multi-layered materials manufactured by bonding high strength skins with low density cores, obtaining composite materials with improved properties. Honeycomb sandwich composites, for example made from aramid fibres and aluminium cores, had their static and fatigue behaviour studied and investigated trough four-point bending tests, in order to analyse how the material would behave when applied to a mechanical component (Belouettar, 2009).

2.4.3 Fabrication considerations

There are several considerations that should be assessed when fabricating a component (Engineers Edge, 2019):

- Product scope and intent; this is the definition of what the product will look like, how it will work, what features it will have, amongst other product characteristics and specifications;
- Time to market; this is the period between the first conceptualization and ideas up to the its eventual availability on the consumer market;
- Cost and competitive environment; the cost of the product should be in line to offers from rivals available in the market, this way the newly developed product can be competitive and successful;
- Organization infrastructure; when developing a product, it is important to plan it with the resources, infrastructure and tools available to the organization in order to make the project possible;
- Design, engineering and manufacturing tools; engineers should plan every step of production in order to minimize costs and maximize cadence and quality of the final product. There are some guidelines to consider when planning the production of a certain component. For example, for high volume parts, it is important to consider

castings, extrusions or other volume-friendly manufacturing processes in order to reduce machining and time-consuming processes. It is also recommended to avoid thin walls, in order to minimize distortions, and eliminate features that overall require special and expensive operations and tools during manufacturing.

2.4.4 Design for excellence

Design for excellence (DFX) is a concept where “X” is a variable that can have one or many possible values and meanings. This gives rise to terms such as design for manufacture (DFM), design for assembly (DFA), design for cost (DFC), design for disassembly (DFD), design for environment (DFE), design for recyclability (DFR), amongst many others. Since there are so many terms that can be applied as goals when designing a product, DFX has been used to characterize and agglomerate all of them. Engineering design is a process of developing a system, component, or process in order to meet desired needs. It is a decision-making process in which sciences, mathematics, and engineering technologies are applied to convert resources in an intended objective (Sanja Aaramaa, 2015).

Before DFX terms existed, engineering design was completely based on the product functionality. The design was passed from the design department to the process-planning department and finally to the manufacturing department. These activities were completed in a sequential manner, in which the designer would not get any feedback about his initial concept. Sometimes the designed product was extremely difficult to manufacture and the manufacturing cost was unnecessarily high. When this happened, a new design had to be made, or the high production costs needed to be sustained. To solve this problem and help the designer reducing the product costs, two approaches can be used. Value engineering and producibility engineering. Value engineering is primarily concerned with product function and costs. On the other hand, producibility engineering assures that product specifications can be met with available techniques, tooling and test equipment’s, at a cost compatible with the product’s selling price. By using both these approaches, design engineers attempt to optimize the design in order to maximize the profit and accomplish the intended functions (Tsai-C.Kuo, 2002).

DFM provides mechanical designers a set of guidelines to follow when developing a product. These include raw material selection, process selection, develop a modular design, use standard components, design parts to be multi-usable, avoid separate fasteners and minimize assembly directions. All parts should be assembled from a single direction, avoiding wasted time and resources and possible assembly errors. By using modular designs and standard components, costs will be lower and the used components are utilized in different applications (Tsai-C.Kuo, 2002).

DFA is based on the premise that the lowest assembly cost can be achieved by designing a product in such a way that it can be assembled by the most suitable assembly method, maximizing both efficiency and final cost. Currently designers, have software’s that will evaluate and assist them in their work. Assembly time simulators, design efficiency indexes and assembly difficulties, are some of the available tools by which the software's aid the designers, in order to achieve the best possible result. DFA criteria has basic guidelines, such as (Tsai-C.Kuo, 2002):

- Minimize the number of parts, fixings, assembly movements, and assembly directions;

- Provide lead-in chamfers, promote automatic alignment of components, easy access to essential surfaces, symmetrical or overstated asymmetrical parts, and easy handling and transportation;

- Avoid visual obstructions, simultaneous assembly operations, parts that may tangle, and adjustments that can affect prior ones.

DFD has a great importance in the design of new components since recycling became an important requirement in recent years. This happens because, in most industrial countries, the amount of discarded products is increasing dramatically. This way, the disassembly of used products is necessary in order to make recycling economically viable in the current state of the reprocessing technology capabilities (Tsai-C.Kuo, 2002).

In Figure 8 it is possible to see the product life cycle using a DFX methodology (Colin H. Simmons, 2012).

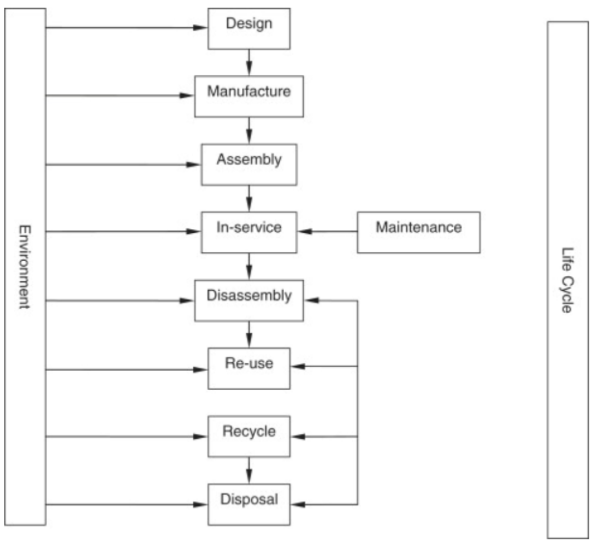


Figure 8 - DFX methodology product life cycle (Colin H. Simmons, 2012).

There are several studies in this area of expertise, some of them are described in the Table 1.

Table 1 - Compilation of studies in the DFX area

Reference	Description
(Telenko, 2016)	In this report, the design for environment (DFE) methodology is studied in order to obtain strategies and guidelines to utilize when designing a component. A total of 6 DFE strategies and 76 DFE guidelines were reconciled from 20 sources. These are intended to be used in early stages of design in order to reduce environmental impacts of products and systems. It was also noticed by the author that conflicts exist between DFE guidelines and others (e.g. design for cost or safety). Thus, a proper evaluation of main objectives and requirements should be made, in order to properly design the component
(J. A. Barton, 2001)	In this paper, the author disputes the fact that the product design determines 70% of total costs as is stated by different entities. No correlation between this numbers was found. However, the author claims that using a new design methodology, "DFEE" (Design for the existing environment), which takes into account the capacity constraints of the actual company, produces the best results when it comes to cost.
(Tsai-C.Kuo, 2002)	In this publication, the author, provides concepts, applications, and perspective of DFX in manufacturing. Thus, providing guidelines to assist each different methodology implementation, depending on the manufacturer and client requirements. Each different methodology has specific guidelines, and multiple methodologies can be used in a single product. By doing so, product development is easier, more sustainable, more profitable and efficient then "un-assisted" product development.

(M. Ashby, 1993)	In this article, the author implements a software that facilitates the material selection procedure in mechanical engineering. It contains a database of quantitative and qualitative data for a wide range of engineering materials. The system has an interactive selection environment, in which different materials are analysed and the best proposals are presented to the user. These software's have been developed in order to ease the material selection processes and are commonly used in the industry.

2.4.5 Assembly considerations

Assembly can be simply and accurately described as the union or fastening of components, materials and subassemblies together into complex products (Zorowski, 2004). This process is also commonly referred to as composing. The assembly process can be characterized by three generic functions. The first one is referred to as the handling function. This is the action of bringing two or more parts into a particular spatial relationship with one another. The second function is joining or fastening, which has the purpose of ensuring the continued relationship of the parts achieved by the handling function, against outside effects. This function can be subdivided into means and mechanisms, in which the means are the specifications and materials that the joining function will rely on, and the mechanisms are the actions that will occur. For example, if two parts are held by a nut and bolt, the mechanism is "joining", and the means is the force required to overcome the friction between the mated parts. The third and final function is checking, which is used to determine if the first two functions have been carried out and the said assembly has taken place successfully. For this to happen the assembly should be present, in correct positioning and the quality of the composition should fulfil the acceptance criteria (Zorowski, 2004).

Product considerations that could reduce cost and simplify operation may dictate the assembly structure. For example, one region of a single component may suffer from more wear than other region from the same component, justifying the separation of the main component in two smaller sub-components. This would only require substitution of a smaller sub-component instead of the full component in case of premature wear of the more stressed region (Zorowski, 2004).

When designing a product and its corresponding assembly structure it is important to consider package size and weight of the final component. More compact and lightweight solutions will be cheaper to transport and overall grant great economic benefits when analysed at a large scale.

An assembly should also be designed with reassembly in mind. If it is a product that requires maintenance, possible repairs or updates it is important that the component can be disassembled, repaired and reassembled once it is repaired. If the product is disposable or does not require any of these procedures, then more permanent mounting methods may be used. Therefore, it is very important, when designing components, to keep in mind how easy it will be to assemble and reassemble the final product.

In order to achieve a successful assembly process and final product it is very important to anticipate assembly related challenges and define the assembly process in order to maintain a correct positioning and respect specified tolerances. Therefore, it is important to design features to guide the assembly process and define the assembly sequence in the most simple, cheapest and less time-consuming way possible. Features can be present on the component such as datum references, guiding surfaces, external features, amongst others, and serve as guidance to correctly assemble the various parts together. When designing hidden features that require a particular orientation; it is very important to provide these external features that will correctly align the part, assuring a correct assembly. This way, it is also advisable that every designed component will consistently orient himself granting a correct positioning. It is advisable to avoid parts that may become tangled, wedged or disoriented and to design fasteners that are large and efficient enough to be easily hand operated. When possible, the use of threaded fasteners such as screws, bolts, nuts and washers should be used, as these can be time consuming to assemble.

When DFM, it is important to avoid tight tolerances if possible. If the tolerances are too tight, the component will be more expensive to produce and the tolerances might be beyond the natural capabilities of the chosen manufacturing processes. Therefore, it is always beneficial to consult with manufacturing early in the design process regarding tolerances, soon as the preliminary sketches are available (OCM Manufacturing Inc., 2019).

2.4.5.1 Datum References

Datum references are theoretical geometries consisting of basic geometric elements of a mechanical part such as a point, axis and plane that will serve as reference in defining its geometry, measurements and tolerances (Yuguang Wu, 2016). It is a reference point, surface, or axis on the component against which measurements are made. When creating and choosing datum references, typically one plane, line and point are chosen and used as reference. Yet, there are other possible datum combinations that can be used, such as three different planes, two lines and one plane, amongst combinations. Different combinations can be used as long as they eliminate the six degrees of spatial freedom that a component can have. Those are, x, y and the z plane translation plus the x, y and z plane rotation (Yuguang Wu, 2016).

For example, in Figure 9, three planes were used as datum references. The first plane, XY, will lock three degrees of freedom - translation in the z-axis, rotation in the x-axis and rotation in the y-axis. The second plane, XZ, will lock two additional degrees of freedom – translation in the y-axis and rotation in the z-axis. Finally, the third plane, ZY, will lock the final degree of freedom – translation in the x-axis. This way, the component is locked and does not have any spatial freedom, meaning that measurements can be correctly defined.

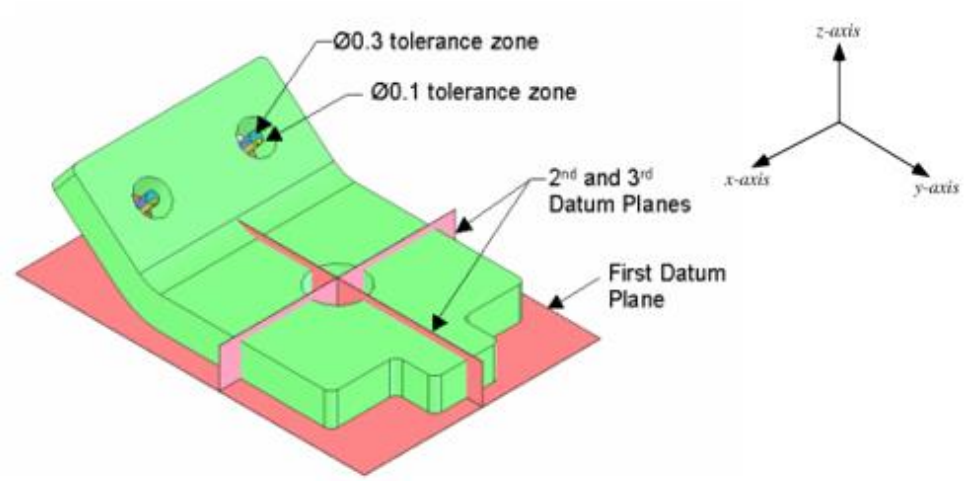


Figure 9 - Three plane datum references (GD&T, 2005)

2.4.6 Rapid prototyping

Prototyping is an essential part of product development and manufacturing cycle, required for assessing the form and functionality of the product. Until recently, prototyping was made by skilled model makers from 2D engineering drawings, which is a time consuming, high-skilled and expensive process. With the evolution of new layer manufacturing and CAD/computer-aided manufacturing (CAM) technologies, prototypes can now be rapidly made from 3D computer models. Rapid prototyping (RP) is a term which embraces a range of new technologies utilized to accurately produce parts directly from CAD models in only a few hours, with little to none human intervention required. RP technologies are divided into processes that involve the addition of material, and processes that remove it. It is claimed that RP can cut new product costs by up to 70% and the time to market by 90% (D. T. Pham, 1998). One of the most recent and most used RP technologies is 3D printing. This procedure employs an additive manufacturing process where products are built on a layer-by-layer basis, through a continuous series of cross-sectional slices. 3D printers work in a manner similar to traditional inkjet or laser printers. Yet, rather than using multi-coloured inks, the 3D printer used powder that is slowly deposited, layer-by-layer. These printers use CAD software that takes thousands of measures of cross sections of each product to determine how each layer is to be constructed. A thin layer of liquid resin is dispensed, which is then hardened by a computer controlled ultraviolet laser. Figure 10 shows this fabrication step for a “Batman” face model. At the end of the process, the excess resin or filler material is cleaned away with a chemical bath and the final prototype is ready. 3D printers are hugely versatile since they can even develop products with free-moving parts that do not have to be post-assembled. 3D printing does not require costly moulds or tools, does not produce scrap or needs finishing processes, it is automated and there is even the chance of recycling any waste material. Considering all this, 3D printing is an excellent RP tool to access the viability of a project (Berman, 2011).

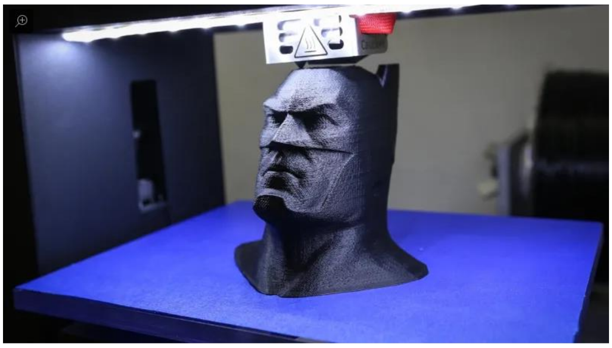


Figure 10 - Printing the "Batman" face on a 3D printer (Martin, 2016)

2.5 Instrument panels

Initially, the word dashboard was used to refer a wooden or leather barrier fixed in the front of a horse-drawn carriage to protect the driver from mud or other debris thrown by the horses hooves (Daddario, 2017). Typically, these components did not perform any additional function besides providing a convenient support to climb to the driver's seat or a small clamp to hold the reins when they were not in use. When the first "horseless carriages" were constructed in the late 19th century, the panel was held to protect occupants from the debris thrown by the front wheels of the cars. However, as the car's design evolved to position the motor in front of the driver, the dashboard became a panel that protected vehicle occupants from the heat and engine oil (Daddario, 2017). With gradually incresing mechanical complexity, this panel formed a convenient location for the placement of gauges and minor controls, and from this it evolved into the modern instrument panel, although retaining its common name. In the first production car, the Ford Model T, produced from 1908 to 1927, the dashboard only came with an ammeter (instrument to measure electric current) as standard equipment (Daddario, 2017).

Nowadays, a dashboard is a control panel located directly in front of a vehicle's driver, displaying instrumentation and controls for vehicle operation (speed indicator, engine speed display, engine temperature display, oil level indicator and others). Since the start of the modern instrument panel development, analog gauges were utilized, until automakers started to introduce digital intrument panels in their cars in the 1970's. During the early stages of this tecnology, these devices had bad reviews since they were hard to see under bright lights, were expensive to repair and took away the sense of continuous acceleration substituting visual paterns with a series of flashing numbers. (Capehart, 2003). Currently, digital gauges are utilized in the majority of cars and motorcycles taking advantage of liquid crystal displays (LCDs), or more recently thin-film-transistor liquid crystal displays (TFT LCDs), since the traditional mechanical instruments lacked the ability to satisfy the market with characters of favorable compatibility, easy upgrading, providing all needed information, and styling (Deepak Mahajan, 2015).

Figure 11 - Porsche 964 RS (left) (Barnett, 2018) and Audi R8 RWS (right) (Iger, 2018) instrument panels

As an essential human-machine interface, the instrument panel provides the drivers with important information of the vehicle. In order to display these valuable driving parameters, a microcontroller is used to process information generated by other electronic control units (ECUs) of the vehicle. Some instruments adopt 8 or 16-bit microcontrollers (MCUs), which have limited peripherals, meaning that they cannot meet some requirements, such as rear-view video and high performing real-time data. This way, high performance 32-bit MCUs should be used when displaying this type of information. MCUs should also have rich peripherals to reduce the need of extra components, thus saving space in the cluster and enhancing the stability of the system. Meanwhile, the operating frequency should be high, and the memory size should be large due to the demand of speed and accuracy in real-time processing. Besides, using multiple built-in regulators and a flexible standby mode allows various operation modes that are needed to lower down the power consumption. Since most of the driving parameters are displayed on the TFT-LCD, and the interface can be designed with immense flexibility by updating the software, the instrument panels can meet different requirements. What kind of driving parameters to display and overall design and layout can easily be changed, which allows for these devices to be compatible in innumerous different applications. This feature brings huge manufacturing and economic advantages since one cluster can be sold and distributed for several clients and still have different appearances and displayed information. This, while still maintaining the same materials, basic design and produced on the same production line. One example of the same product used in different applications is the Volkswagen AG (VAG) group cluster shared by the 2019 Lamborghini Urus and 2018 Audi RS5, Figure 12. In this case, there are software and front frame changes that alter the final appearance of the instrument panel (Prior, 2019).

Figure 12 – Instrument panels of the Lamborghini Urus (left) (Prior, 2019) and Audi RS5 (right) (Chan, 2018)

2.5.1 General concept

2.5.2 Powered two-wheeler cluster

The cluster of a PTW or a similar two or three-wheeled vehicle is known to comprise one or more instruments into a single instrument panel. This panel allows the user to analyse multiple information about the vehicle. This information ranges from vehicle speed (speedometer), engine rpm (tachometer), fuel consumption, remaining fuel, selected gear, operating temperatures and pressures, amongst many others (Figure 13).

As mentioned earlier, it is usual that the instrument panel comprises several individual instruments, which have evolved from mechanical to electronic components in recent years. The objective with this change was to eliminate the low accuracy levels and overall size and bulk of these mechanical components since they are fitted in the front region of a motorcycle, which is usually a region of critical dimensions. Nevertheless, the digital technology used in control panels initially had its own flaws, since this technology and liquid crystals, found in LCD applications, used to have certain limitations. Increase in brittleness, operation limitations due to temperature variability, low graphic power (due to the crystals being monochromatic) and a considerable reduction in contrast as the external light level increases were some of them (Italy/Varese Patent No. 6060985, 2000). However, with the evolution of this technology, most of these limitations are now very limited or non-existent.

Figure 13 - Ducati Monster 821 cluster (Campbell, 2019)

2.5.2.1 *Front Frame*

An instrument panel front frame (Figure 14) is a bezel that protects and confers appealing aesthetics to the instrument panel assembly. The front frame, together with analogic dials, in older vehicles, or with LCDs, in newer vehicles, will be the interface that is facing the user and providing all the vehicle information. Therefore, it should be simple, intuitive and have a pleasant design. Furthermore, it also protects the internal components of the assembly, and it should not let particles and liquids into the component.

Figure 14 - BMW front frame (ECS Tuning, 2019)

2.5.2.2 Rear Cover

An instrument panel rear cover (Figure 15) is a component that, similarly to the front frame, will act as a barrier between the internal components and the exterior environment. It may or may not also act as a structural component of the assembly, depending on the requirements. On the rear cover there are components such as vents, assembly pins, guiding features, glue conduits, screw holes, amongst other features depending on the application.

Figure 15 - BMW rear cover (ECS Tuning, 2019)

2.5.2.3 TFT displays

A thin-film-transistor (TFT) display is a variant of a liquid-crystal display (LCD) that uses a sandwich-like structure that contains liquid crystals filled between two TFT glass plates (Figure 16). A transistor is made from a thin film of amorphous silicon that is deposited on a glass panel. This film will only occupy a small fraction of the area of each pixel in order to allow light to easily pass through. However, when high performance is expected from the TFT LCDs, which happens in small dimension high-resolution displays, polycrystalline silicon is used instead of the regular amorphous silicon, which is cheaper and easier to produce.

TFT glass has as many TFT's as the number of pixels displayed, the colour filter glass has a colour filter that allows the generation of colour. Voltage alteration is induced between the colour filter glass and the TFT glass, promoting the movement of the liquid crystals. The differences in voltage will cause the alteration of the molecular structure of the liquid crystals, allowing different wavelengths of backlight to pass-through the assembly. The light is supplied by a white bright backlight or light emitting diodes (LED), and ultimately the amount of light and colour generation that the display will emit is determined by the amount of movement of the liquid crystals (Shelly Inc, 2019).

Currently, TFT LCDs are used in many applications, both in automobiles as in PTWs. They are used in instrument panels, AC and audio controllers, navigation devices or other video inputs. In comparison with regular LCDs (same basic structure but without the presence of transistors directly in the glass), TFTs have a sharper and brighter image while displaying information more quickly and more smoothly. Although, when it comes to power usage and cost, LCDs are usually more efficient. Yet, the equipment consumption is mostly affected by the backlight, which means for example that a LED TFT LCD can be more efficient than a traditional white bright backlight LCD (Sniderman, 2019).

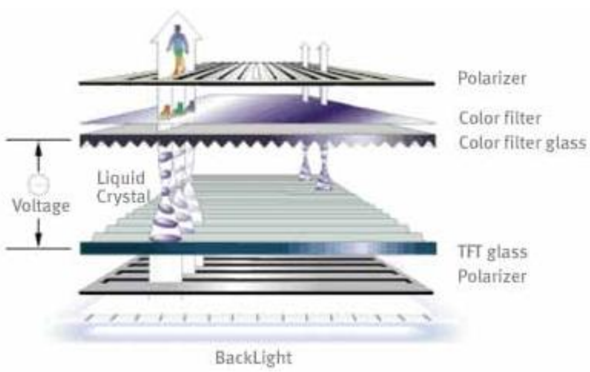


Figure 16 - TFT display structure (www.web.archive.org, 2019)

2.5.2.4 PCB

A PCB (Printed circuit board), Figure 17, is utilized to support and connect electronic or electric components using conductive tracks, pads and other features from sheets of copper and sheets of non-conductive substrate, mostly grade four flame retardant (FR-4) glass epoxy. PCB's were initially referred to as "printed wiring boards" because they replaced common electrical wiring with a landscape of conductive paths on a rigid surface (LaDou, 2006). These boards can be made from a single layer of copper (single-sided), assembled in a sandwich of two externals layers of copper with a non-conductive substract in between (double-sided), or, in several intercalated layers in which the outer and inner ones are cooper, alternating with non-conductive substracts (multi-layer). Components are then soldered onto the PCB in order to connect them and mount them in place. Additionally, PCBs may have a coating that protects the copper from corrosion and prevents solder shorts. This is one of the cheapest and most effective methods of producing electric circuits, since the components are assembled and wired in a single, automated operation. Multi-layer PCBs are the ones that allow a higher number of components to be added, since the circuits of the inner layers would otherwise take up surface space between components. However, these suffer from impracticability when it comes to repairs, analysis and field modifications, since many of the components are in the inside layers (Singh, 2018).

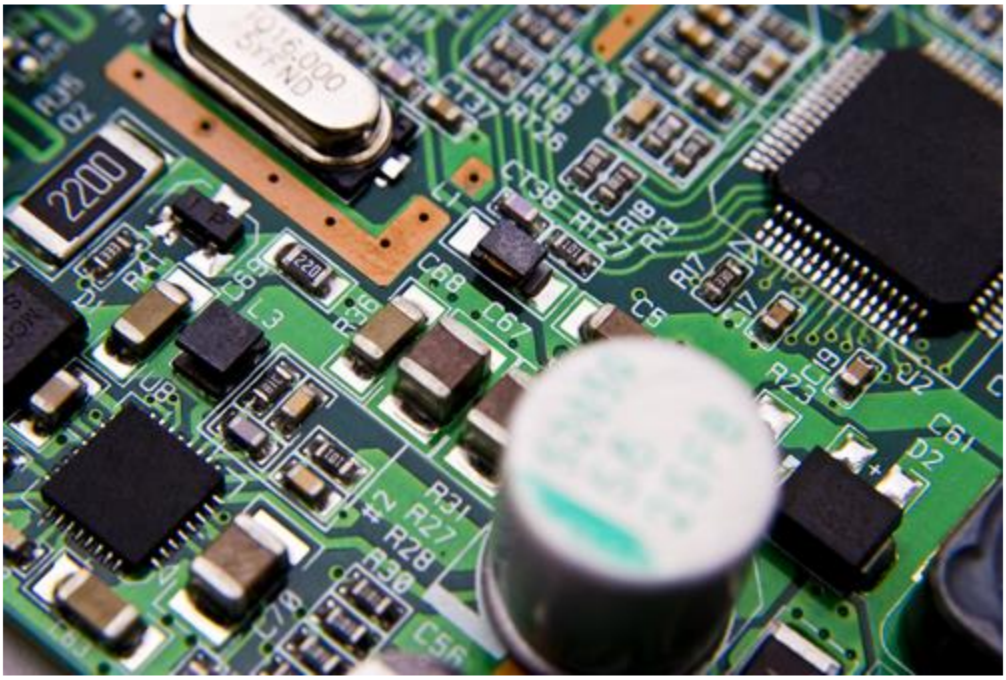


Figure 17 - Printed circuit board (Thomas Industry, 2019)

2.5.2.5 FFC (Flexible flat cable)

Flexible flat cables (FFCs), Figure 18, are designed to hold any number of electrical components or as a singular connector between two circuits. For example, in a cluster, FFCs are commonly used to connect the PCB to the LCDs (Lorom Industrial, 2015). These are utilized instead of regular round cables to simplify cable management, especially in applications where high flex is required. They take less space, have better suppression of electromagnetic and radio-frequency interferences and eliminate tangling and coupling of the wires. Additionally, since the wires are individually protected and not wrapped many times like round cables, they end up being lighter and offer better flexibility, meaning they can be shaped to fit tight and unusual system requirements. FFCs can then be used in a variety of different applications, especially in those where flexing, tight routing and motion are required. There are three main FFCs types (Gannon, 2013):

- Flexx-Sil, which uses an exclusive material and patented extrusion process that produces a cable that is resistant to extreme temperatures, wear, cracking and deformations caused by vibration, water, ice, sparks, steam, humidity, UV light, autoclave and most chemicals.

- Polytetrafluoroethylene (PTFE), which uses two Teflon® shell halves that are bonded together while clamped wires are maintained in place. This design and production methods are optimal to use in cleanrooms since they will reduce the production of gases and particles. The final product is able to withstand high voltages and to operate in temperatures ranging from cryogenic to 260°C without losing flexibility. Although this material suffers from low resistance to abrasion and cutting forces, these characteristics can be enhanced if this is required by the application.

- Moulded, which are manufactured by stretching the wires between clamping pins in a mould and then pouring liquid silicone or polyurethane and respective additives over the wires. Although they are not as resistant as the competitors, they still offer high flexibility with a thin and compact design, but the main advantage is the lower production cost.

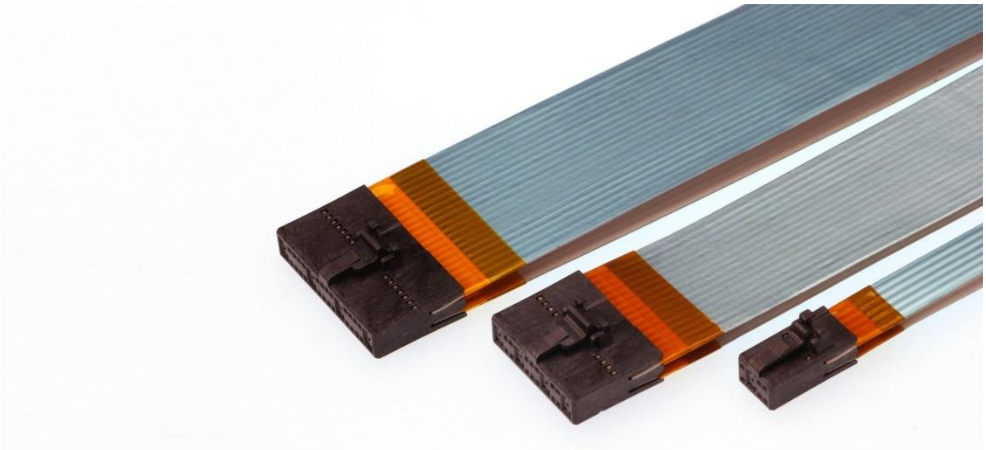


Figure 18 - Flexible flat cable (Lorom Industrial, 2015)

2.5.2.6 GORE venting plug

GORE vents (Figure 19) are able to manage the internal pressure in different electronic enclosure applications, preventing deformations and possible component failure.

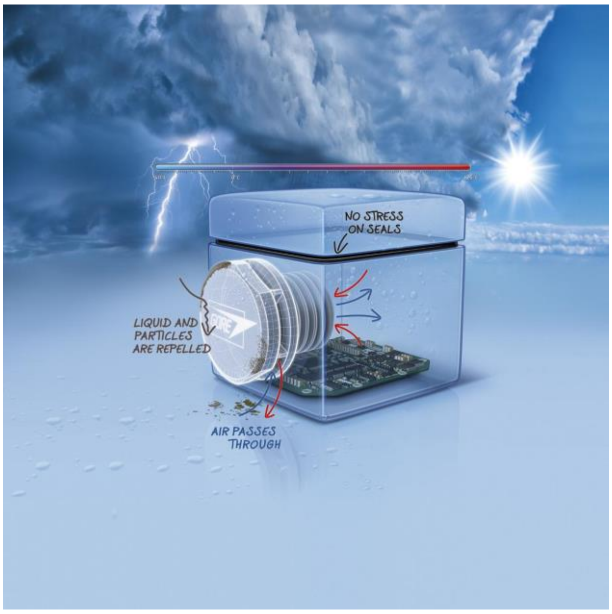


Figure 19 - GORE vent (Gore, 2019)

Electronic enclosures, as PTW instruments clusters, which are in direct contact with the environment, suffer from pressure variations caused by the different temperatures at which they are exposed. If any of these electronic components were to be exposed to water, dust and other environmental factors, their integrity and performance would be at risk. This way, a solution that allows a complete protection against these threats but at the same time can allow pressure changes in the electronic enclosure is necessary. The usually utilized solution is the application of GORE vents. These are plugs that will allow enclosures and containers to breathe, equalizing pressure and reducing condensation while filtering out liquids and other contaminants. A microporous PTFE membrane made from gore prevents pressure build-up by constantly equalizing the difference in pressure between the side enclosure and the outside environment (Gore, 2019).

2.5.3 Adhesive Bonding

To promote the union between the front frame and the rear cover, adhesive bonding is usually used. Adhesive bonding is a versatile technique in which the adhesive will cause the union between two similar or dissimilar materials (Figure 20). Adhesives have great advantages when compared to other commonly used methods (Troughton, 2009), such as:

- Allowing to join different substrates with different geometries;
- Eliminate the risk of corrosion associated with joining two dissimilar metals, since these can react with each other and cause this occurrence;
- Not causing any mechanical aggression to the substrate, unlike for example welding, which can cause dimensional alterations and tension build-ups;
- Reduction of weight when compared to other joining procedures;
- Increased resistance to impact and to fatigue, since adhesives have better elastic properties than other methods of joining;
- Homogenous distribution of tensions throughout the union, which eliminates stress concentrations on specific points of the components caused by other methods;
- Reduction of noise and vibrations;
- Improve sealing and overall protection;
- Reducing mechanical components in the assembly, such as screws, nuts, washers, rivets, amongst others.

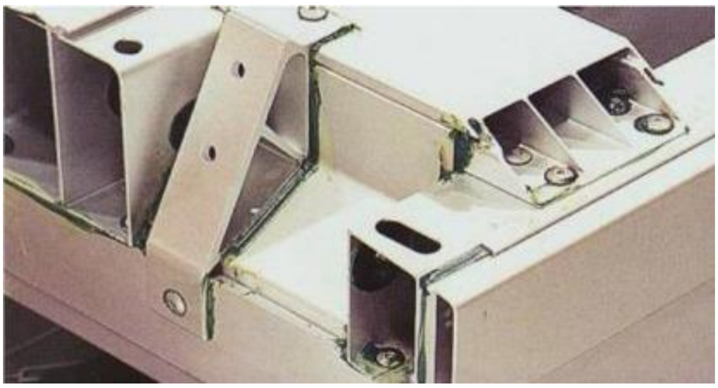


Figure 20 - Adhesive bonding used in a Lotus chassis (Association, 2015)

Additionally, in LCD applications, where the LCD display is joined to the front glass a different type of adhesive is utilized. This bonding procedure is called optical bonding, since the adhesive is specific to this application and maintains or enhances the optical properties of the display, while joining and protecting the two components at same time (Ray-Jay Jeng, 2018).

2.5.4 Background

The 2-wheeler motorized vehicles population - which includes motorcycles, scooters and mopeds - has been constantly increasing for the past few years. In most "Organisation for Economic Co-operation and Development" (OECD) countries, between 2001 and 2010, the motorcycle fleet increased at a much higher rate than the passenger car fleet (adapted from International Transport Forum, (2015)). As such, PTWs are becoming a very important constituent of the transportation structure. However, they represent the highest risks when it comes to road safety, bringing a big challenge to transportation entities. The International Transport Forum set up a Working Group on the Safety of PTW's in 2010 to review trends in powered two-wheeler crashes and examined the factors contributing to these crashes and their severity (adapted from International Transport Forum, (2015)). Important topics were analysed, such as user behaviours, the use of protective equipment and the vehicle and infrastructure quality and integrity.

The number of PTW's on the road is growing at a fast rate and they play a significant role in mobility in many countries, particularly in many of the world's large cities, where traffic is denser. While some riders use PTWs as their primary form of transportation, others use them for recreational purposes, so the market is very broad. For many users, especially in the least developed countries, the PTW is the only affordable or practical means of individual motorized mobility. Yet, PTW riders are at far more risk than car drivers per kilometre ridden, both in terms of fatalities as of severe injuries and long-term disabilities. Moreover, this type of vehicle has not benefited at the same rate as cars from safety improvements over the recent decades. In the OECD countries, PTW riders represent 17% of total fatalities on average, while PTWs account for about 8% of the motorized vehicle fleet. PTW fatalities often represent a much higher proportion of total fatalities in low and middle-income countries. In addition to the human casualties, the economic costs associated with PTW crashes are quite significant. Therefore, researching and investing in PTW safety can both bring social and economic benefits (adapted from International Transport Forum, (2015)).

PTW crashes are frequently linked to failures of perception and control of the vehicle. The most frequent PTW fatal crashes are collisions at intersections. These commonly involve problems of perception and appraisal by both the driver and the rider. Other great impact cause are single-vehicle crashes, mainly due to the fact that PTW's have a higher sensitivity to external perturbations, caused either by road surfaces or weather conditions. Speeding and consumption of alcohol and drugs are also critical factors in the occurrence and severity of PTW crashes, just as for other road users (adapted from International Transport Forum, (2015)).

2.5.4.1 Crash characteristics

In recent years, the rapid market growth of PTW's in most countries has been accompanied by a consequent growth in crashes, injuries, and fatalities involving them. As world population continues to grow, it is likely that even more people start to recognize the potential of the economic, mobility, and environmental sustainability benefits of PTWs. PTW riders experience a greater risk of being severely injured than other road users, yet they carry less risk for others due to having less weight and size when compared to cars and trucks. As seen in Table 2, there are three types of crashes involving PTW, these are single vehicle crashes, multi vehicle crashes and crashes involving pedestrians. The type of accident that causes most deaths are multi vehicle crashes (30 – 50% of fatalities).

Table 2 - Fatalities in crashes involving PTWs, (adapted from International Transport Forum, (2015))

Single vehicle crashes (20-45% of fatal crashes)	Poor road design and conditions Lack of riding technique and competences Influence of alcohol Mechanical problems Other
Multi vehicle crashes (30-50% of fatal crashes)	At junction Not at junction with vehicle in the same direction Not at junction with vehicle in the opposite direction Other
Crash with pedestrians (<10% of fatal crashes)	Collision with pedestrians

There are many possible causes of multi vehicle crash occurrences, but the most notable ones are collisions at junctions, rear-ending the vehicle in front or lane changing by the PTW user. The last two are mostly caused by the user taking his eyes of the road or the lack of visibility of incoming traffic. In the past decade, PTW users' safety has deteriorated when compared with the significant progress for other road users. This happened due to the large increase in PTW numbers on the road, since they allow better mobility and are more economic when compared to their counterparts. This information stresses the importance of taking immediate appropriate countermeasures in order to provide added safety for all road users (adapted from International Transport Forum, (2015)).

2.5.5 PTW mirrors

A PTW mirror is usually a mirror glass mounted within a plastic or carbon streamlined mirror housing. Motorcycles, identically to other vehicles, have mirrors in order to allow the riders to have a better perception of their surroundings. These features have existed for many decades ago and are still used today. Nevertheless, they do carry some drawbacks. Motorcycle mirrors affect the vehicle overall drag resistance, which influences fuel economy and performance, only allow limited visual awareness of the surroundings and suffer from fogging and poor visibility at night. New technologies and concepts are pushing the envelope and replacing these features with side view cameras that transmit the image at the instrument panel. This allows the removal of the entire mirror assembly, which would benefit the PTW efficiency, safety and aesthetics (Abdulkareem Al-ObaidI, 2018).

Cameras would provide a better and cleaner image both during the day and night hours. This technology can attenuate sun glare and improve poor lighting and visibility situations. By reproducing the image in the instrument panel, the user can maintain its sight forward instead of looking at the sides. By removing the mirrors, the frontal surface area is diminished and drag coefficient is improved, which translates into higher fuel efficiency and better performance (Abdulkareem Al-ObaidI, 2018).

2.5.6 Mirror aerodynamic drag

Drag or air resistance is a mechanical force that acts opposite to the relative motion of any object moving in relation to a surrounding fluid (NASA, 2019). This occurrence can happen between two fluids or between a fluid and a solid surface. In the case of a motorcycle travelling at speed, the resistance happens between a solid body (motorcycle) and a fluid (air), and the magnitude of the skin friction depends on properties of both solid and fluid. For the solid, a smooth and waxed surface produces less friction than a roughened one. For the fluid, the resistance depends on the viscosity of the air and the relative magnitude of the viscous forces to the motion of the flow, expressed by the Reynolds number. Shape also determines drag resistance. As air flows around a solid body, the velocity and pressure at each point are changed. Pressure variations arise from the momentum of the gas molecules, which produces a force. Thus, a varying pressure distribution around the body will produce a similar variation on force. Considering this effect, a body should be as aerodynamic as possible to flow through the fluid. Aerodynamic properties have a considerable effect on speed, downforce, fuel consumption, efficiency, stability, amongst others, therefore being a very important component when developing a vehicle. Pressure acts perpendicularly to the solid surface of an object, this way the direction of the force on a small section of the object is along the normal to the surface. The normal direction changes from each section of the motorcycle creating zones with different pressures and airflow. The aerodynamic drag is equal to the sum of the product of the pressure times the incremental area in the normal direction. This way, for a fluid in motion, the velocity has different values at different locations around the body, since the local pressure is directly related to the local velocity (NASA, 2019).

Motorcycles usually have poor aerodynamic properties when compared with automobiles. Usually, cars have an average drag coefficient (c_d) of 0.3, while a race motorcycle (as seen in Figure 21) has a c_d of 0.6, while a regular motorcycle can have a c_d of about 1.8. Once air crosses the trailing edge of a motorcycle's fairing into the open space between the fairing and rider, laminar flow disintegrates. For example, the air pocket behind the windscreen and the area behind the rider are highly turbulent zones. When travelling at speed, air pressure rises to the cube of speed, which means that for every km/h the corresponding air resistance increases by a multiple of three. This way, when a motorcyclist is travelling at 100 km/h, 80% of a motorcycle's energy is spent overcoming air resistance (Guide, 2016).

Figure 21 - Wind tunnel testing of a Ducati GP motorcycle (Guide, 2016)

In most production motorcycles, maintaining rider comfort is the aerodynamic goal. This way, reducing wind noise, heat dispersion and increased stability are the main concerns. According to Wolf-Heinrich in “Aerodynamics of Road Vehicles” (Hucho, 1993), exterior side view mirrors can increase aerodynamic drag between 2 and 7 percent. This added drag will have an impact on fuel consumption. Considering this, is easy to see that motorcycle aerodynamic properties will suffer from having side mirrors, obstructing air flow and decreasing overall efficiency. George Claypole, a vehicle integration engineer that works for GM's Advanced Technology Vehicles, claimed that a mirror, which includes a mirror glass mounted within plastic streamlined mirror housing, can increase a vehicle cd by about 0.03 (William L. Shepard, 2000). The Alliance of Automobile Manufacturers and Tesla Motors calculated that a 10 percent decrease in aerodynamic drag would cut fuel consumption by 3.2 percent (Chong, 2014).

This way, using a PTW as an example it is possible to simulate the impact in surface area the removal of the mirrors would cause. The motorcycle used to test this impact was a Honda CBR 1000RR Fireblade SP1 and, using an area calculator tool, it was determined that the total frontal area represented 0.4 m^2. Using the same tool it was determined that each mirror had a surface area of 0.014 m^2, Figure 22. This means that the total surface area without the mirrors would be:

Awm – Total frontal surface area without mirrors

At – Total frontal surface area

Am – Frontal surface area of one mirror

$$Awm = At - 2 * Am$$
$$Awm = 0.4\, m^2 - 2 * 0.028\, m^2$$
$$Awm = 0.372\, m^2$$

The initial area was 0.4 m^2 and the final area was 0.372 m^2,

$$x\,\% = (0.372 * 100)/0.4$$
$$x = 93\,\%$$

This way, it is possible to see that removing both mirrors in a Honda CBR 1000RR Fireblade SP1 could reduce the surface area up to 7%, thus boosting fuel efficiency.

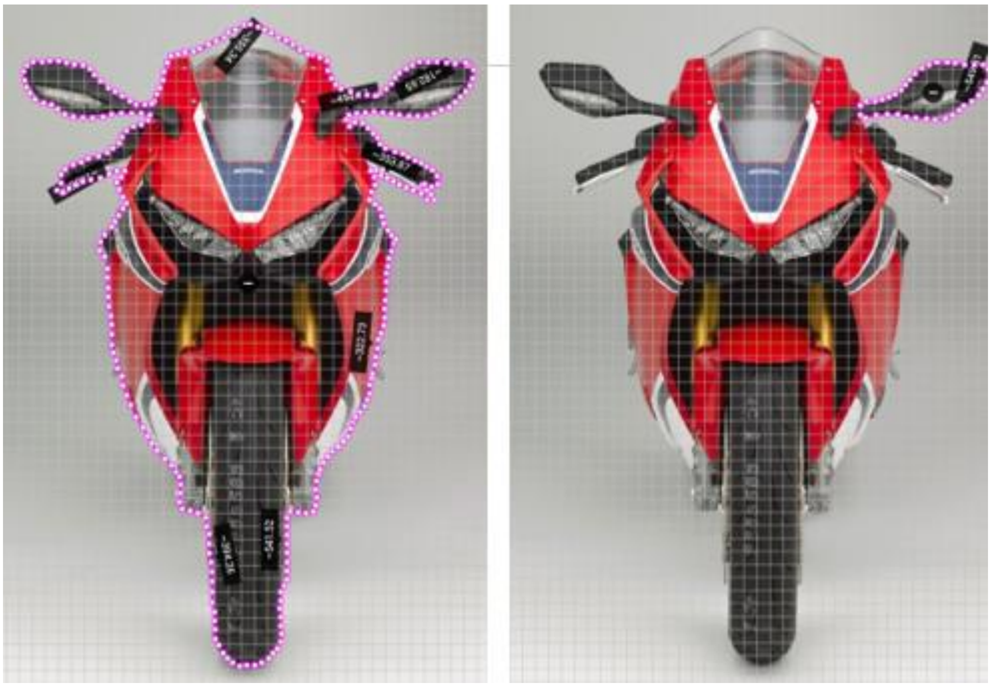


Figure 22 - Honda CBR 1000RR Fireblade SP1 frontal surface area (self-elaboration)

According to a forum user, the removal of one single mirror in is car yielded a 2.3% fuel economy increase which translated in 0.09 liters of fuel saved per 100 km (MetroMPG, 2006).

2.5.7 Safety

It is possible to eliminate blind spots by using a wide-angle lens and image processing to provide a far wider field of vision than traditional mirrors. In addition, they can place the screens and relocate them where the driver most easily sees it, as opposed to mirrors, which must be positioned to afford the best rearward view. For example, pearl auto Rear Vision wide angle camera can cover up to 180° field of vision. It has two precise HD cameras, one is optimized for daytime, while the other is infrared sensitive to be able to provide clear images during night time. It also has a hydrophobic coating to repel water and the power supply is made by solar energy that charges an internal battery (Pearl Auto, 2019). Although, the camera wide angle can cover up to 180°, distortion usually occurs in the borders of this type of camera. This way the optimal solution would be to use two similar cameras in both sides of the rear of the motorcycle, giving a very wide angle of view to the user as seen in (Figure 23). Other great advantage of using cameras is the adaptation to the exterior lighting. Cameras can tone down glare or provide a clearer and brighter image during the night, which are both beneficial to the user and increase the quality of the visual information provided (Habibovic, 2017).

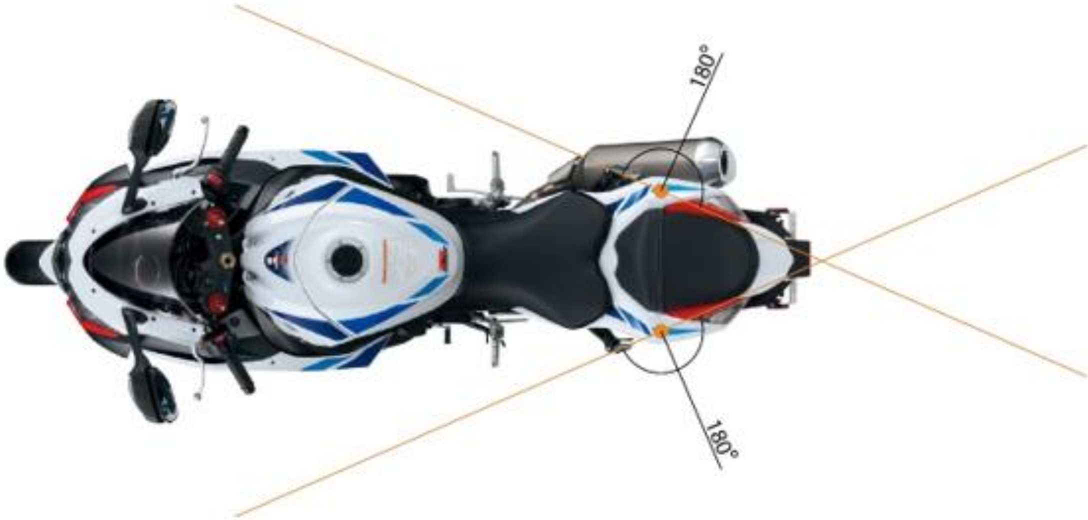


Figure 23 - Wide angle cameras field of vision (self-elaboration)

2.5.8 Legislation

Legislation is quite harsh when it comes to do revisions in topics that involve safety. Therefore, this technology needs to meet international standards and the slow processes that come with it. For example, in the United States of America, there are state laws that differ between states, which means that, while in some states it would be legal to use PTW's without mirrors, in the rest it would not be possible. The Auto Alliance is recommending that any change to the federal law should supersede individual state laws (Lavrine, 2014). As mentioned earlier, changing legislation requires a huge effort and companies such as Tesla tried to change them in a short time and were not able to put this technology in production. For example, the Tesla Model X, a crossover utility vehicle, was supposed to substitute both mirrors with external cameras. Yet, since the deadlines arrived and no approvals were made, the version that was commercialized came with standard mirrors instead (Lavrine, 2014).

The Tesla Roaster (Figure 24) is the next model from the company to be planned to start production without standard mirrors. Nathan Taylor, which is a spokesperson from the National Highway Traffic Safety Administration, claimed that the agency is taking these requests seriously (Lavrine, 2014).

Figure 24 - Tesla Roadster concept (Singleton, 2017)

The first country to change legislation in favour of this technology in passenger vehicles and trucks was Japan, in 2016, soon followed by the European Union. However, currently there are very few vehicles on the road taking advantage of this technology (Omoto, 2018).

The VW XL1, which was a limited production vehicle; with only 250 units sold to the public, was the first vehicle to be sold with cameras replacing the side view mirrors, in 2013 (Car Magazine, 2013). Nevertheless, the first series-production vehicles to be produced offering a setup such as this will be the Audi E-Tron and the 2019 Lexus ES (Green Car Reports, 2019).

In the 2019 model of the Mercedes Actros truck (Figure 25) the first production truck in the world to feature cameras as side mirrors, the standard setup was replaced with a system called "MirrorCam" that comes standard in this model. Mercedes claims, that by replacing the conventional mirrors and wide-angle mirrors with this new system, a considerably improved all-round view and performance is achieved. In addition the omission of mirrors reduces fuel consumption, as the compact digital cameras bring considerable aerodynamic advantages to the vehicle (Mercedes-Benz, 2019). Other companies are planning to use this technology in future applications, such as BMW, Mitsubishi, Lexus, amongst others (Omoto, 2018).

Figure 25 - Mercedes-Benz Actros 2019 with the “MirrorCam” technology (Mercedes-Benz, 2019)

Passenger vehicles and truck manufacturers are pathing the way, when it comes to integrating this technology in all vehicles. This will help to standardize legislations around the globe and facilitating the entry of this technology in the PTW’s market.

THESIS DEVELOPMENT

3 THESIS DEVELOPMENT

3.1 Company description

3.1.1 Bosch Group

The history of the company started in a backyard in Stuttgart on 15 November 1886, when 25 years old Robert Bosch founded the "Workshop for Precision Mechanics and Electrical Engineering". From the very beginning, the company's history has been characterized by innovative strength and social commitment. Currently, The Bosch Group is a leading global supplier of technology and services.

Several first steps were given by Robert Bosch, the step into independence, onto the automotive market, into external makerts (outside Germany) and onto the factory floor of major manufacturing facilities. Bosch started by performing all the precision mechanical and electrical engineering work that came his way. When asked to build a magneto ignition device for a stationary engine in line with an existing design, he improved it and paved the way for magneto ignition production. From this point forward, Bosch started installing magneto ignition devices into automobiles and further developed the product into a high voltage magneto ignition system with spark plug, therefore branching the company over Europe and becoming a world leading automotive supplier. The first international advertisement and public recognition of the company occurred when the Belgian driver Camille Jenatzy drove a Mercedes to victory in the Gordon Bennett Cup thanks to a very reliable Bosch ignition system (Figure 26) (Bosch Global, 2019).

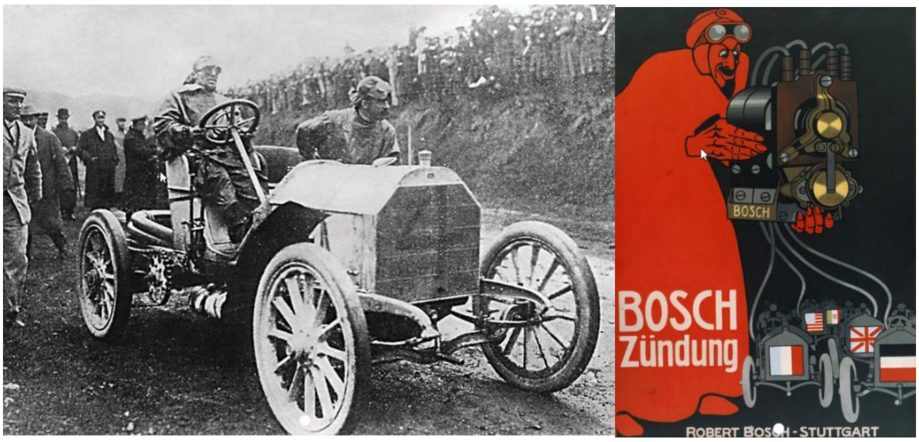


Figure 26 - Jetnazy in his Bosch equipped Mercedes during the Gordon Bennet Cup in Ireland (Bosch Global, 2019).

After an advertisement for the magneto system in the U.S. newspapers, Bosch doubled his sales within a year, therefore starting his globalization process. In 1913, 88% of sales were achived outside of Germany. During this period of expansion, Bosch was able to be represented in 6 continents and 90% of british made cars had a bosch magneto system. When automobiles and motorcycles became everyday objects, new products were developped – lights, generators and starters (Figure 27) (Bosch Global, 2019).

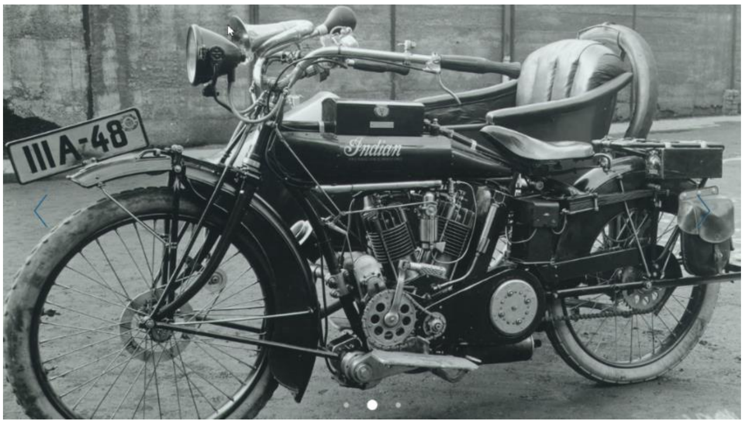


Figure 27 - Bosch lights in an 1921 Indian Motorcycle (Bosch Global, 2019)

The company huge success was briefly interrupted during the first world war where Bosch stopped its usual production, research and development in order to manufacture grenade detonators. After the world war, there was an oppening for new companies to enter the market. Therefore, Bosch focused his efforts into innovating and creating new products like motorcycle and bicycle lights, wipers, horns and battery powered ignition.

In 1927 came to fruition the diesel-injection pump that would last up to this date. This type of engine wouldn't require a magneto ignition so Bosch could provide solutions and products for both types of engine. In 1939 Bosch was ordered to to research and develop gasoline injection for aircraft engines and television tecnhology that were of huge interest to the military. Robert Bosch died during the second world war in 1942 and left clear instructions to his sucessors on how he wanted them to run the factory. The twenty following years were devoted to reconstruct the brand and increase international presence and sales in which Bosch developped kitchen appliances, electronic components (such as transistors and integrated circuits), power tools (Figure 28) and gasoline injection systems that would increase performance and improve fuel efficiency (Bosch Global, 2019).

Figure 28 -- Bosch Power Tools manufactured in 1952 (Bosch Global, 2019)

In the 1960s, Bosch started to diversify as a group with self managed divisions producing power tools, automotive solutions, appliances and overall engineering solutions. With the advance of times, electronics were further studied, originating the electronically controled "Jetronic" injection system, lambda sensors and anti-lock braking system. Bosch also ventured into telecommunications during two successful decades before withdrawing from several segments regarding this technology (Bosch Global, 2019). In the ealry 1990s, Asia provided new markets, and software evolution oppened new business opportunities for Bosch, which started developing microelectrical mechanical sensors (MEMS) for use in automobiles. These worked like sensory organs that would measure acceleration, rotation, pressure, airbag deployment, amognst many other functions. MEMS for consumer electronics were also developped, making Bosch the current manufacturing world market leader. Automotive innovations became the Bosch signature image, developing the electronic stability program (ESP), *TravelPilot* navigation system, Common Rail high pressure diesel injection sytem (Figure 29), DI Motronic gasoline direct injection, adaptive cruise control and Night Vision. In the early 2000s, Bosch acquired industrial tecnhology specialist Mannesmann Rexroth and Thermology specialist Buderus AG (Bosch Global, 2019).

Figure 29 - Bosch common rail diesel injection system and Travel Pilot navigation system (Bosch Global, 2019)

More recently Bosch established new business fields such as small, lightweight devices with lithium-ion batteries, e-bicycles, web-enabled household appliances, self-driving automobiles and others. Currently there is a huge focus on automated driving therefore the researching and developing in this area is bigger than ever, Bosch currently is testing and researching solutions to implement this technology as soon as 2020 (Bosch Global, 2019).

3.1.2 Bosch in Portugal

In Portugal, Bosch has been present since 1960 with their inauguration of a retailer in Lisbon, Robert Bosch, S.A. Currently the company is represented by Bosch Termotecnologia in Aveiro, for hot water solutions; Bosch Car Multimedia Portugal S.A. in Braga, for car multimedia solutions; and Bosch Security Systems in Ovar, for security comunication systems.

Bosch Car Multimedia Portugal S.A. was founded in 1990 and its the main factory of the Multimedia Car division and the biggest of the Bosch Group in the country. Currently, Bosch Car Multimedia S.A is working on the development and production of innovative car multimedia solutions. Such as, head-up displays, automotive and 2-wheeler clusters (instrument panels), gestural and haptic sensors in order to improve the Human Machine Interface (HMI), infotainment systems, vehicle-to-vechicle (V2V) comunnication systems and steering angle sensors for the car's electronic stability control (ESC). The team is heavilly focused on developing technologies to V2V communication, which will bring Bosch one step closer to fully automated driving (Bosch, 2019).

3.2 Work objectives and requisites

The main goal of this project was to develop and make a production study of a motorcycle cluster prototype. The cluster has the objective of eliminating the need of mirrors in motorcycles, which has security, design and aerodynamical advantages over the current products in the market. Usually, motorcycle mirrors are small sized and give limited information to the user, which most of the time resorts to rotate his head backwards in order to reassure himself it is safe to change direction or to change lanes. This can be a huge hazard, since it can be the cause of accidents and fatal injuries. This new system, in which the mirrors would be incorporated into the motorcycle dashboard, improves greatly the amount of visual information that is available to the user. This way, the rider can always maintain his head facing forward when driving. Aerodynamics are also improved, since the absence of the mirrors have a positive impact when it comes to vehicle dynamics and fuel consumption.

3.3 Timeline

The curricular internership took place at the ENG building located at Bosch Car Multimedia S.A. Portugal in Braga (Figure 30). Teams that work there exclusively develop products and systems to be utilized the automotive and motorcycle industry, such as clusters, head-up displays, steering angle sensors, amongst others.

Figure 30 - ENG department at Bosch Car Multimedia S.A. Portugal in Braga (self-elaboration)

The internship started in the 17th of September and ended in the 31st of May. The integration process took place between the 17th and 28th of Setember and the project development started in the 1st of October and ended in the 31st of May.

In order to allow a easy contextualization and integration on the Bosch company and respective team, there was an integration process during the first two weeks. This process had has an objective to informe all new employees of the company's working methods and procedures. Therefore, during the three weeks of this process, socialization, bonding and mutual aid are encouraged through the development of several group activities supervised by a psychologist who acts as a facilitator. This way, it is possible to smooth the entry into the company, transmit methodologies and, above all, transfer positive learning to new employees, transforming this integration process into an enriching experience for each individual.

In addition to the different group tasks proposed during the integration process, this initial stage also includes several visits to different areas of Bosch and a series of trainings for all new employees about several topics. These will range from Health, Safety and Environment; Information Security and Privacy; Electro Static Discharge (ESD); Product Engineering Process and Bosch Production System Basics.

During the integration process, there is also where you first have contact with the team that you will be integrated to, in which each member briefly presents himself and his respective role.

This integration process is a mandatory requirement in the division where the internship took place, ENG departement, and it is necessary that all new members submit to this procedure. At the end, the new members compille all relevant information reunited through the first two weeks of the integration process and post it on the company wiki page. This way, future associates can access the information and experiences shared by previous company members providing a smoother entry into Bosch Car Multimedia.

3.4 Product to design

As mentioned earlier, the basic concept to be developed is a solution to replace PTW mirrors for rear-view cameras and place the image transmitted from the cameras in the instrument panel. From a design and usability standpoint, the instrument cluster must be well placed and easy to see. Motorcycles have limited space when compared to automobiles and trucks, therefore there is a bigger challenge in adapting this technology into a PTW. Furthermore, as this technology still has not found its way into the PTW market, the concept can be studied and developed using different approaches when it comes to visibility, camera placement and design integration in the instrument panel. The basic idea was to remove the mirrors entirely and install rear view cameras in the rear sides of the motorcycle, giving a much broader vision angle and increase the overall perception of the user surroundings.

3.5 Brainstorming of ideas

Initially, the brainstorm of ideas started by researching some current products manufactured in Bosch, i.e. the Porsche 992 and VW Touareg clusters. The first sketch (Figure 31) was based on a curved display and was composed by three different active areas. There would be two side displays, each of them to process the information given by each corresponding side view cameras, and a single display in the middle, which would function as a regular motorcycle cluster, providing detailed information about the vehicle. Curved displays were first introduced in the 2019 VW Touareg (Figure 32).

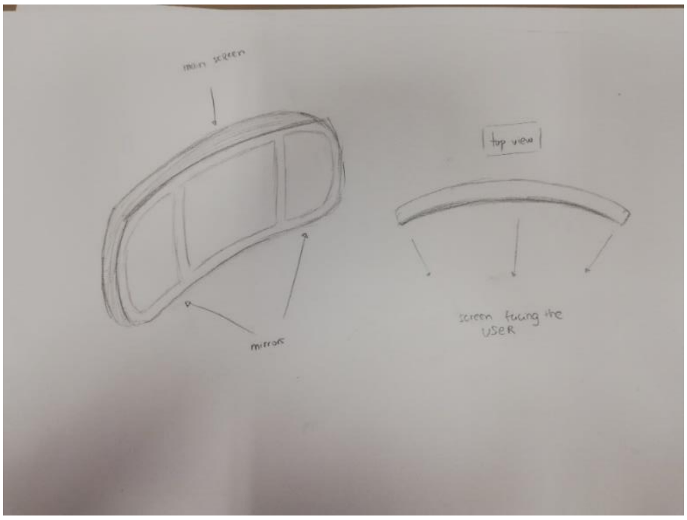


Figure 31 - Initial sketch of a curved display (self-creation)

Figure 32 - Curved display in the 2019 VW Touareg (Volkswagen, 2019)

After this first concept, a different approach was taken, in which the curvature would be obtained by placing three flat LCD's at an angle with each other. This design has been used, for example, in the new Porsche 992 (Figure 33), Panamera and Cayenne, in which the center LCD is in a flat positioning and the two side LCD's are tilted towards the driver.

Figure 33 - Three flat Lcds "Curved" display in the Porsche 992 (Miller, 2019)

For the first months, it was necessary to get acquainted with the work methods and interface of the software in order to be able to develop the final product.

After analysing several products, including powered two-wheeler clusters, the approximate dimensions that the final component should have were decided, keeping in mind it should fit different types of motorcycles. In Table 3, a brief analysis was made to different motorcycles from different segments, in order to determine the area and format that the cluster could have.

Table 3 - Different motorcycle clusters and layouts (Bosch Intranet, 2019)

Motorcycle	Instrument panel
BMW F850	
Honda GL1800 Gold Wing	
Honda PCX	

By analysing the approximate area, layout, possible application in different segments of motorcycles, and similar products, the shape and dimensions were defined in an interval of values, to be used as reference. The width should be between 320 - 360 mm, while the height should be between 80 – 120 mm.

3.6 Draft project

3.6.1 Idea selection

Initially the idea of developing a cluster that would eliminate the need of mirrors in PTW was a challenging one since it is a big change in the segment. The basic concept was that the developed cluster should feature a single curved LCD, or three flat LCD's in which the two external ones would be tilted towards the user at a specific angle. The curved display was initially developed to compensate for the image distortion that occurs due to the difference between the distance from the viewer to the screen centre – d2, and between the distance from the user to the screen edges – d1 and d3 (Figure 34). A flat LCD will have different measurements to the centre (d2) and to the edges (d1, d3). The least variation that exists between these distances, the least distortion the image will suffer. As it is represented in Figure 34, the distance d2, has the same value as the distance d1 and d3. This means that the image does not suffer from distortion, and it is as close to reality as possible. The same theory can be applied when the side screens are tilted towards the user, although, unlike it happens in the curved display, the distance is not always the same. Yet, with this layout, the distances d1, d2 and d3 are very similar among themselves, which allows less image distortion than in a flat display application.

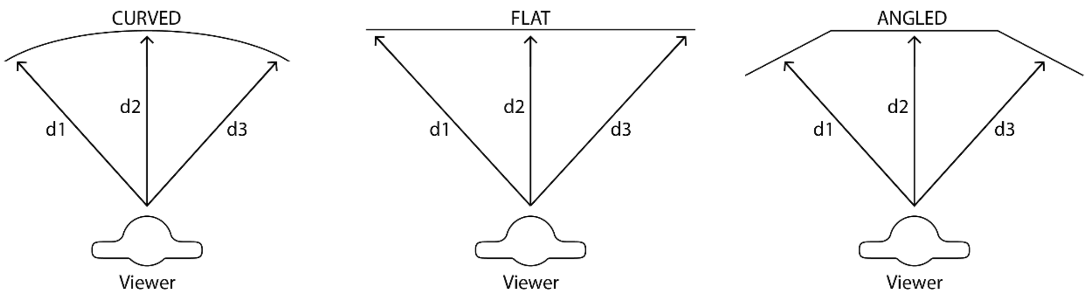


Figure 34 - Curved, flat and angled instrument panels

A single LCD curved display would be ideal from a design point of view, usability and user preference, although it would bring additional mechanical challenges and considerable price increases (Byeonghwa Choi, 2015). When considering that this new concept of instrument panel would need to be competitively priced, the cheaper and more cost effective way to implement this technology would be by resourcing to the design with three flat LCDs tilted at the user, which is a great compromise between the flat and curved solutions.

3.7 Design

3.7.1 Component design

Instrument panels have been evolving in the past years, going from analogic to digital, and adding innovative features and technology at each new iteration. Integrated side view mirrors, which are already seen in a few production vehicles, could soon be making their way into the motorcycle industry. When using this technology, the user needs to be able to visualize incoming traffic in the instrument panel. Mirrors are slightly tilted to the motorcyclist in order to allow visual information processing while driving (Figure 35). This means the rider requires less head movement and allows the eyesight to be centred with the incoming road. Considering this, the design was based on a curvilinear shape faced to the user. Thus, the motorcyclist could have easy access to information about the motorcycle and its surroundings.

Figure 35 - Mirrors tilted towards the rider (Speed, 2019)

In order for the motorcyclist to get a wider angle of view of the incoming traffic, the recommended mirror positioning is as seen in Figure 36 - Motorcycle side mirror correct positioningFigure 36. By positioning the mirror as seen on the right image, the mirrors will provide a wider image reflection, while at the same time reducing the mirror overlap. Yet, it is important to remember that the farther the external parts of the mirrors are, the higher deformation the image will suffer (Throw, 2018).

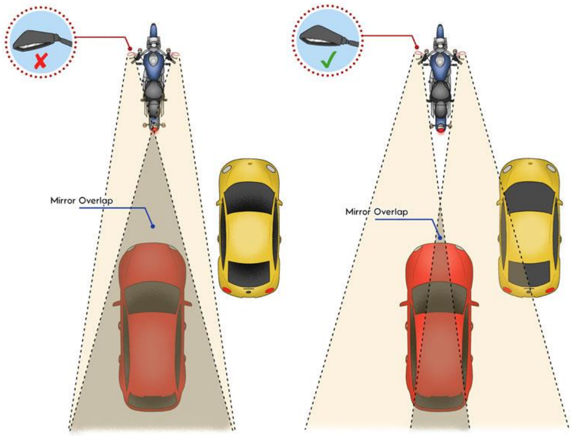


Figure 36 - Motorcycle side mirror correct positioning (Throw, 2018)

3.7.2 Modelling the CAD part

An essential part for the development of the final component was to understand the cluster design, by analysing current produced products and by developing iterations of 3D models. The utilized software was “computer-aided three-dimensional application version 5” (CATIA V5). CATIA is a multi-platform software suited for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), product lifecycle management (PLM) and 3D analysis, developed by Dassault Systèmes.

For the first months of the internship, it was necessary to get acquainted with the work methods and interface of the software in order to be able to develop the final product. There were several sketches, concepts, and cad models made in order to refine the product at each iteration. Some iterations are presented in the images below. In the Figure 37, a rounded shape with a honeycomb reinforcement is used.

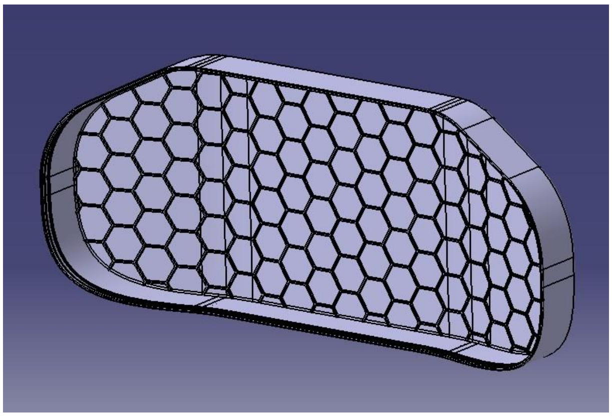


Figure 37 - Example of a curved rear cover iteration

Later, in Figure 38, a display reused from another project was placed to simulate an assembly and to have a visual conception on how the concept would function.

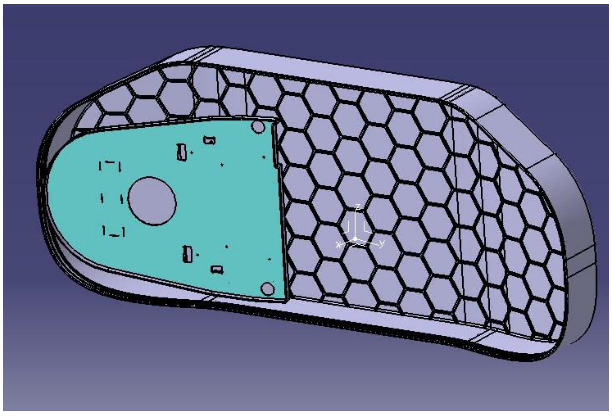


Figure 38- Example of a curved iteration with a prototype display

For example, in order to analyse other visual appearances for the instrument panel, a rectangular bent shape, with round corners (Figure 39), was also designed. The LCDs were placed as an assembly in order to simulate the final product.

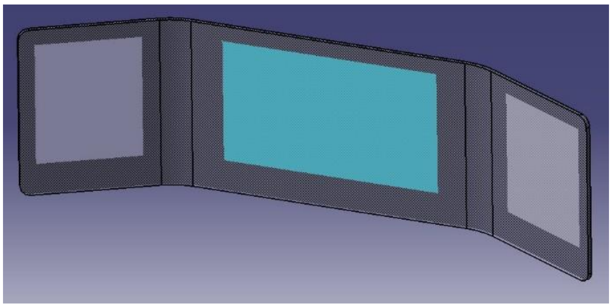


Figure 39 - Example of an angular flat instrument panel iteration

The final iteration, and chosen concept, was based on the previous design. The side displays were rotated 90°, the instrument panel was extended in width, and shortened in height at both the extremities, as seen in Figure 40.

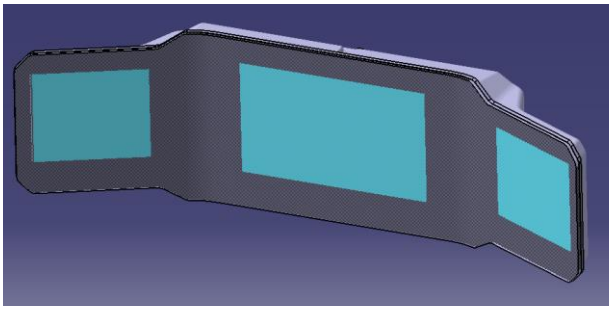


Figure 40 - Final instrument panel concept

3.8 Material selection

3.8.1 Requisites

In the following tables, the material requisites (Table 4) and respective properties (Table 5) are analysed in order to select the best materials for both the front frame and back cover applications. As both components have similar applications when it comes to protecting the internal components and sealing the assembly, similar requisites were also considered.

Table 4 - Material requisites

Number	Requisite	Justification
1	Lightweight	Weight savings became a standard procedure in the transportation industry since they allow higher efficiency. While it might seem negligible in smaller components, it adds up into considerable weight reduction on the final product.
2	Impact resistant	The rear cover should be resistant to impact since a crack or fracture could allow water into the cluster and damage the internal electronic components, causing severe damage.

3	Stiffness	The rear cover is the main structural component of the assembly. Thus, it should be stiff enough to maintain form and function.
4	Do not oxidize	Since the cluster is for a motorcycle application, it is important to be protected against the surrounding environment.
5	Wear resistant/durable	Motorcycles can be used on a daily application; therefore, the material should be durable and resistant in order to fulfill user expectations.
6	Low cost	Cost is always a parameter to have in consideration, since a product needs to be profitable and at a competitive price to be successful.
7	High mechanical strength	Overall, mechanical strength is very important, especially since the back cover is a structural component that has a great contribution in maintain the assembly together.
8	Waterproof	The back cover material needs to be waterproof in order to protect the internal components.
9	Light transmittance (front frame)	The front frame material should allow light transmittance, in order for the image to be visible by the user.

Table 5 - Material properties

Number	Requisite	Properties
1	Lightweight	Low density
2	Impact resistant	High resilience and high toughness
3	Stiffness	High elasticity modulus
4	Do not oxidize	High corrosion resistance
5	Wear resistant/durable	Medium/high hardness (in order to ally with high toughness)
6	Low cost	Low cost
7	High mechanical resistance	High tensile strength and compressive strength
8	Waterproof	High impermeability
9	Light transmittance (front frame)	High luminous transmittance

After analysing the tables presented, it is possible to see that both the front frame and rear cover should have similar specifications, such as low weight and considerable mechanical properties, in order to originate a reliable and resistant final component.

3.8.2 Material families

As seen in Figure 41, materials can be divided into six different families, which are:

- Metals, these are materials that show a lustrous appearance when prepared and that conduct electricity and heat considerably well. Metals vary in properties and can belong to different groups such as ferrous (based on iron) and non-ferrous, brittle, refractory, amongst others. Metals can also be composed of two or more different elements, in different ratios, in which at least one of them must be a metal. When this happens, the material is called an alloy. Metals are usually malleable, heavy, ductile, good conductors of heath and electricity, and offer a great impact resistance and toughness. However, there are innumerous metals with a great array of different specifications and properties, which means they can be useful in many different applications (William F. Gale, 2003).

- Ceramics, these are inorganic, non-metallic, crystalline, solid and inert materials. They usually have high melting temperature, high hardness, poor conductivity, high modulus of elasticity, great chemical resistance, high fragility and low ductility. There are some exceptions in the ceramics family, for example, there are also non-crystalline ceramics, which tend to be formed from melts that are casted, and posteriorly heat treated. Ceramics are divided into four main types: structural, refractories, whitewares and technical, and are used in several different applications, such as sanitary products, tiles, disk brakes, bearings, amongst others (Shi, 2012).

- Glasses, these are non-crystalline and amorphous materials that are derivative of common minerals, they are characterized by their high silica content and are largely used due to their transparency to visible light. They are a product of a fusion which was cooled to a rigid condition without crystalizing. Glass has a great electrical insulation, fire resistance, dimensional stability and a low thermal conductivity. Although it presents high hardness and scratch resistance, it is also brittle and breaks easily against impact solicitations (Shelby, 2005).

- Elastomers, these are polymers with great viscoelasticity and a very weak intermolecular force and Young's modulus. Since they are easily deformable, they are particularly suited for applications such as seals, adhesives and flexible components. They can be natural or synthetic products and have been used for centuries because of their deformable properties. They can be described as a high molar mass material which, when deformed at room temperature, reverts quickly to its original size and form when unloaded (Kalle Hanhi, 2007).

- Polymers, these are a large molecule, or macromolecule, composed of many repeated units. Repeating units are usually made from compounds of carbon and hydrogen (hydrocarbons). However, they can also be made from oxygen, nitrogen, sulphur, chloride, fluorine, phosphorous and silicon. Polymers range from synthetic plastics such as polystyrene (PC) to natural biopolymers such as deoxyribonucleic acid (DNA). Both natural and synthetic polymers are created via polymerization of many small molecules, known as monomers. Thanks to their large molecular mass relative to their small molecule compounds, they feature unique physical properties when compared to other materials. The majority of manufactured polymers are thermoplastics, which allows easy processing and facilitate recycling. Yet, there is another group of polymers, addressed as thermosets, which will degrade when reheated. Polymers offer substantial qualities, such as high resistance to chemicals, high electrical and thermal insulation, low weight, easy processing and have an almost limitless range of characteristics and colours. Polymers can be used to make components that have no alternative from other materials, as it happens in blood bags, which extend the blood's shell-life (Council, 2019).

- Composites, these are engineered or natural occurring materials composed from two or more constituents with distinct physical or chemical properties, which remain separate within the finished structure. Composites can be divided into two major types, structural composites, which have remarkable mechanical properties, and functional composites, with considerable physical, chemical and electromechanical properties. By combining different materials, it is possible to produce materials with great properties and a large array of applications (Hu, 2012).

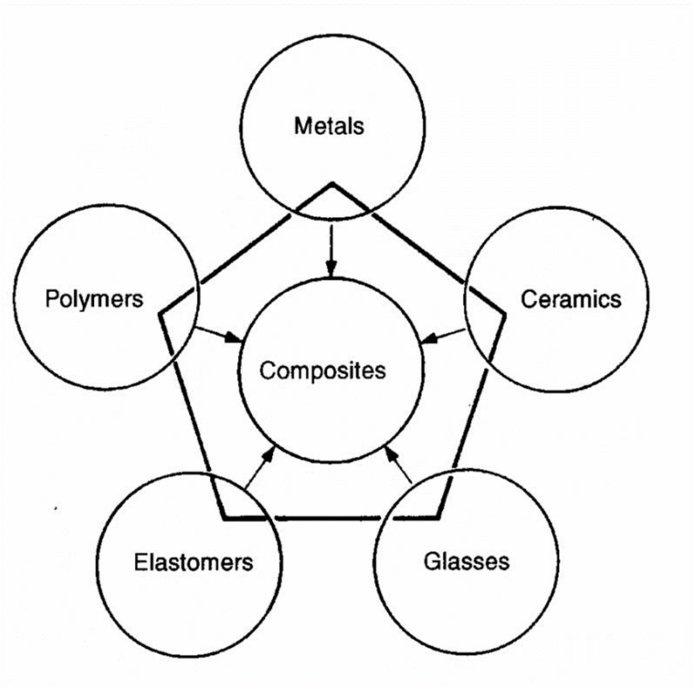


Figure 41 - Material families (Kuliah, 2011)

When analysing which material families would be ideal for the instrument panel, there were families that were automatically excluded since they did not fulfil the specifications criteria. Those material families are presented in Table 6.

Table 6 - Excluded material families

Excluded Material Families	Reasons
Metals	Metals are usually heavy; lighter metals will command higher prices; generally, they have worse fatigue strength properties and will tolerate less deflections without deforming when compared to polymers and composites.
Ceramics	Ceramics are usually brittle; have low ductility; poor tensile strength; are difficult to shape and machine.
Elastomers	Structurally fragile and easily deformable, therefore not a possible option in this sort of component.

3.8.3 Material characteristics

When choosing and selecting materials to use in part fabrication, it is important to define what are the highest priorities that the final product should fulfil in order to be successful and obtain good results. Both the back cover and the front frame should have similar properties considered when choosing a material, such as density, impact strength, tensile strength, elongation, modulus of elasticity and price. Density is important since PTW components should be lightweight in order to be more efficient. These components should have a high impact strength in order to maintain form, prevent fractures that can originate water leaks and have a negative visual impact. Tensile strength is the amount of resistance that a material can sustain when under tension. Thus, a stronger material is preferred since it offers more resistance to daily usage. Elongation is how much a material can deform itself before breaking. A material that can suffer a lot of elongation is more resistant to fracture although it can sustain higher deformation, which is also not ideal to maintain dimensional tolerances. Modulus of elasticity is the material resistance to being deformed elastically when a force is applied, so a higher modulus of elasticity is preferred since the material is stiffer. It should also come into consideration that the front frame should be transparent in order to allow the propagation of light through the material.

3.8.4 Considered materials

Considering the previous characteristics, the materials analysed for the front frame were:

- Polymethyl methacrylate (PMMA), which is also known as acrylic or pexiglass, is a transparent thermoplastic often used as an alternative to glass. It is lightweight, strong and offers high mechanical and thermal resistance. PMMA also transmits up to 92% of visible light at 3 mm thickness and has a significant environmental stability allowing it to be a great option for outdoor applications. PMMA cannot undergo through large plastic deformations at ambient temperature since it is brittle and may crack, which difficult its processing (Michael Ashby, 2018).

- Acrylonitrile butadiene styrene (ABS), which is a thermoplastic polymer that is very tough and can sustain high impact forces, it is also known for having high stiffness and offering high heat resistance. The proportions between acrylonitrile, butadiene and styrene can be altered, in order to change properties such as impact resistance or even to be prepared for different manufacturing processes, such as injection or extrusion (Michael Ashby, 2018). ABS is widely used in the transportation sector, although it can be damaged by sunlight. This caused one of the most expensive automotive recalls in US history (8.4 million vehicles affected), where seatbelt buttons suffered high degradation. Since the application would be for a motorcycle, the sunlight exposure would be a limiting factor to the use of this material, although additives could be used to counteract this effect (J.M.Henshaw, 1999).

- Polycarbonate (PC), has a very high impact resistance and can be easily deformed without breaking, which allows it to be easily processed. However, when compared to materials used in similar applications, it has less UV tolerance, and offers a lower resistance to scratches. Coatings can be helpful to overcome these problems making PC a very utilized product in the mechanical industry (Michael Ashby, 2018).

- Gorilla Glass is a chemically strengthened glass that its extremely damage resistant. It is mostly used in displays since it offers low reflectivity and high protection against fingerprint smudges (Corning Inc., 2019).

For the rear cover the following materials were considered:

- 20% talc-filled polypropylene (PP TD20) is a low-density thermoplastic polymer, which offers high toughness, flexibility, high chemical resistance, environmental stress resistance, fatigue resistance and ease of machining and processing. Talc, which is a hydrated magnesium sheet silicate, offers higher stiffness, better surface aesthetics, lower coefficient of thermal expansion, lower shrinkage, and improved scratch resistance than the respective non filled PP. When adding talc, the flexural modulus increases to the expense of tensile strength (Shri Kant, 2013).

- Polyphenylene sulfide (PPS), is an organic polymer that exhibits a great balance of properties, it has excellent mechanical and chemical resistance, high temperature performance, high modulus of elasticity, dimensional stability (very important for manufacturing parts with tight tolerances), high electrical insulation properties and it is flame retardant. PPS can be optimized with reinforcing fibres and fillers, in this case a glass-mineral fibre filled PPS will be analysed (Michael Ashby, 2018).

- Polybutylene terephthalate (PBT) is a thermoplastic polymer, offering high resistance to solvents, good dimensional stability, high mechanical and heat resistance, and can be treated and enhanced with the addition of glass fibres. However, it need UV protection and its very sensitive to hot water (Michael Ashby, 2018).

- PBT + polyethylene terephthalate (PET) with 30% glass fibre reinforcement (GF30), corresponding to a PBT and PET blend with fiberglass reinforcements. It has great mechanical strength, stiffness, chemical resistance and dimensional accuracy, which are essential for the components to be produced (Michael Ashby, 2018).

3.8.5 Properties

The main properties analysed were:

- Density; is the property that correlates the amount of mass that an object has and its volume. This means that, for a specific part, the denser material will increase the final weight when compared to a less dense one. When it comes to vehicle efficiency, weight has a big contribution. Therefore, a material with less density is favoured, when choosing between different options (Michael Ashby, 2018).

- Tensile strength; is a property that it is vastly utilized when studying and comparing different materials. It is the capacity that a material has to withstand opposing forces that will act in an outward direction. These forces will cause elongation of the material until a breaking point. The tensile strength before breaking its the highest force that the material can support before failing (Michael Ashby, 2018).

- Elongation; is the ratio between the size at the initial measure and final measure of a sample right before the material breaks. This will show how much deformation the material can sustain before shattering (Michael Ashby, 2018).

- Modulus of elasticity; measures the material resistance to being deformed elastically (in a non-permanent way). A higher elastic modulus will be associated to a higher stiffness of the material. The material utilized should be stiff enough to withstand forces without being deformed. Therefore, a higher modulus of elasticity is preferred (Michael Ashby, 2018).

- Impact strength; is the resistance that a material will offer to an impact with another object. This is a very important property since the final product will be unprotected and exposed to the environment and must maintain mechanical stability during its lifecycle (Michael Ashby, 2018). When it comes to testing impact strength according to the DIN EN ISO 179 method (Figure 42), some materials are too resistant to be tested in a conventional un-notched shaped sample. If the sample is not fractured by the ISO 179/1eU impact test, then the ISO 179/1eA method should be used. In this method, the material sample should have a slit were the impact will occur, which facilitates breaking (Figure 43) (UL TTC, 2019).

DIN EN ISO 179 method

Method name	Test speci-men	Dis-tance be-tween sup-ports	Notch shape	Notch radius	Re-maining height /width	Direc-tion of impact
ISO 179/1eU	80 x 10 x 4	62	un-notched			e = edge-wise
ISO 179/1eA	80 x 10 x 4	62	V	0,25	8	e = edge-wise

Figure 42 - DIN EN ISO 179 method (UL TTC, 2019)

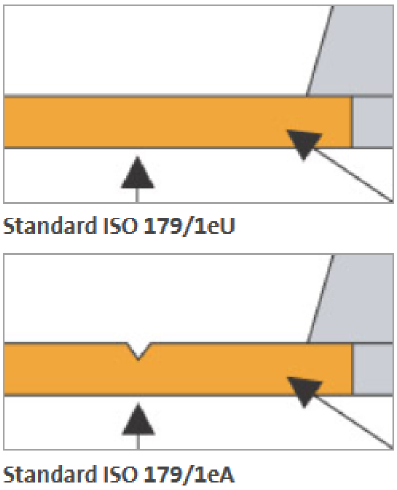


Figure 43 - Notched and un-notched samples (UL TTC, 2019)

- Cost, this is the final property that should be considered. Cost has a considerable significance since it can define the validity of the project. If the component is too expensive to manufacture, then the project may not advance into production. This way, it is important to maintain the costs as low as possible.

3.8.5.1 Front frame

In Table 7, the considered materials for the front frame were analysed and compared. All properties were consulted in "Material information system" (MATIS), which is an internal software in Bosch intranet.

Table 7 - Front frame material properties

Requisite	Properties
Material – PMMA Supplier – Evonik Name – Pexiglass 8N	Average price: 1800 €/ton Density: 1.2 g/cm^3 Impact strength (23 °C): 13 kJ/m^2 Impact strength, notched (23 °C): 1.6 kJ/m^2 Tensile strength at break: 70 MPa Elongation: 2.5 % Modulus of elasticity: 3000 MPa Luminous transmittance: 92 %

Material - ABS Supplier – Terlux Name – HD2802	Average price: 2400 €/ton Density: 1.08 g/cm^3 Impact strength (23 °C): 120 kJ/m^2 Impact strength, notched (23 °C): 5 kJ/m^2 Tensile strength at break: 48 MPa Elongation: 4.0 % Modulus of elasticity: 2000 MPa Luminous transmittance: 90 %
Material - PC Supplier – Covestro Name – Makrolon 2405	Average price: 3000 €/ton Density: 1.22 g/cm^3 Impact strength (23 °C): -- kJ/m^2 Impact strength, notched (23 °C): 62 kJ/m^2 Tensile strength at break: 65 MPa Elongation: 3.5% Modulus of elasticity: 2000 MPa Luminous transmittance:89 %
Material – Glass Supplier – Corning Name – Gorilla glass V6	Average cost: 29000€/ton Density: 2.43 g/cm^3 Impact strength (23 °C): N kJ/m^2 Impact strength, notched (23 °C): -- kJ/m^2 Tensile strength at break: -- MPa Elongation: 9 % Modulus of elasticity: 77000 MPa Luminous transmittance: 90.5 %

By analysing the different materials considered for the front frame, it is important to choose the solution that will provide the best final product. Since the front frame will be manufactured by sheet bending the original product, mineral glass will be much harder to work with. Therefore, although gorilla glass may provide excellent properties, it will suffer from this disadvantage during manufacturing and will command a higher price in comparison to thermoplastics.

ABS also offer great qualities when it comes to mechanical performance, although in is natural state the material is opaque. This means that, in order to be utilized in the front frame, where light transmission is a mandatory requirement, it must be modified, which will increase overall complexity and costs.

PC and PMMA are very comparable plastics. While PC has higher chemical resistance and impact strength it is surpassed by PMMA in light transmittance, scratch resistance, material aging (going yellow over time), cost and sustainability, since it can be remoulded and recycled.

In Table 8, the properties of the materials considered for the front frame are compared. A number from one to ten is given accordingly to each property of each material, in which one is the lowest score and ten is the highest. In the case of gorilla glass, the impact strength and tensile strength specifications are not available from the spec sheet. Therefore no score is given in those properties.

Table 8 – Front frame materials comparison

PROPERTY / MATERIALS	PMMA	ABS	PC	GG
COST (P1)	8	6	5	2
DENSITY (P2)	8	10	8	5
IMPACT STRENGTH (P3)	3	5	10	--
TENSILE STRENGTH (P4)	10	5	9	--
ELONGATION (P5)	8	5	6	3
MODULUS OF ELASTICITY (P6)	8	5	5	10
LUMINOUS TRANSMITTANCE (P7)	10	6	8	9

After all material properties are given a score, it is necessary to analyse how important each property is, both for the performance and for the viability of the final component. In Table 9, it is possible to see that analysis. To each property, a score from one to five is given, being that one is the lowest score and five is the highest. This way, properties with higher relevance for the rear cover have a higher impact when choosing the material. In the final column of the table it is represented the sum of all property values of each material. The material that gets the highest score is the most recommended to use in the manufacturing of the rear cover. As gorilla glass properties are not complete (P3 and P4 are not in the spec sheet), two scores are given, one if the value of these properties was one and other if the value of this properties was ten.

Table 9 – Front frame materials selection

	P1		P2		P3		P4		P5		P6		P7		Σ
PMMA	8	5	8	3	3	4	10	4	8	3	8	5	10	5	230
ABS	6		10		5		5		5		5		6		170
PC	5		8		10		9		6		5		8		208
GG	2		5		--		--		3		10		9		129/209

After analysing the tables above, it is possible to see that there are two materials that can be considered to manufacture the front frame, since their values are very close to each other. PMMA and PC are two very comparable thermoplastics, while PC has higher chemical resistance and impact strength it is surpassed by PMMA in light transmittance, scratch resistance, material aging (going yellow over time), price and sustainability, since it can be remoulded and recycled. Considering this PMMA pexiglass 8N will be used.

3.8.5.2 Rear cover

In Table 10, the considered materials for the rear cover were analysed and compared. All properties were consulted in Bosch intranet software “MATIS”.

Table 10 - Rear cover material properties

Material	Properties
Material - PP-TD20 Supplier – Boarealis Name – Daplen MD231U	Cost: 1420 €/ton Density: 1.03 g/cm^3 Impact strength (23 °C): 24 kJ/m^2 Impact strength, notched (23 °C): 3 kJ/m^2 Tensile strength at break: 32 MPa Elongation: 15% Modulus of elasticity: 2400 MPa
Material - PPS Supplier – Solvay Name – Ryton BR111 BL	Cost: 1600 €/ton Density: 1.91 g/cm^3 Impact strength (23 °C): 16 kJ/m^2 Impact strength, notched (23 °C): 6.9 kJ/m^2 Tensile strength at break: 145 MPa Elongation: 0.8 % Modulus of elasticity: 16000 MPa
Material - PBT Supplier – BASF Name – Ultradur B4520	Cost: 1500 €/ton Density: 1.29 g/cm^3 Impact strength (23 °C): 200 kJ/m^2 Impact strength, notched (23 °C): 4 kJ/m^2 Tensile strength at break: 60 MPa Elongation: 3.7% Modulus of elasticity: 2200 MPa
Material – PBT + PET – GF30 Supplier – Ticona Name – Celanex 2302 GV1/30	Cost: 700 €/ton Density: 1.52 g/cm^3 Impact strength (23 °C): 35 kJ/m^2

	Impact strength, notched (23 °C): 6 kJ/m^2
	Tensile strength at break: 125 MPa
	Elongation: 1.8%
	Modulus of elasticity: 8500 MPa

Usually, PP-TD20 is widely used in plastic components on the transportation sector although it is not a good material to manufacture structural components from. Since PP-TD20 is not as stiff as other thermoplastics, it suffers from high deformation under load. When it is filled with Talc, PP can also demonstrate a poor surface appearance, therefore having some disadvantages.

PPS offers very good mechanical properties and the best performance for the considered application, yet it is the most expensive material, which can limit the project viability. It has a noticeable dimensional stability, chemical resistance and electrical insulation properties and it is easily processed.

PBT is very versatile with a good range of properties, it has excellent electrical properties and with excellent impact strength and abrasion resistance. However, since PBT is very anisotropic in shrinkage, it is difficult to mould it to higher tolerances.

PBT+PET – GF30 is a PBT and PET blend with a 30% glass fibre filler, combining high strength and stiffness with excellent processing characteristics.

In a similar manner to the analysis made previously for the front frame, the properties of the materials considered for the front frame are compared in Table 11. A number from one to ten is given accordingly to each property of each material, in which one is the lowest score and ten is the highest. In the case of gorilla glass, the impact strength and tensile strength specifications are not available from the spec sheet. Therefore no score is given in those properties.

Table 11 – Rear cover materials comparison

PROPERTY / MATERIALS	PPTD20	PPS	PBT	PBT+PET
COST (P1)	8	7	8	10
DENSITY (P2)	10	6	8	7
IMPACT STRENGTH (P3)	5	4	10	6
TENSILE STRENGTH (P4)	4	10	6	8
ELONGATION (P5)	2	10	5	7
MODULUS OF ELASTICITY (P6)	5	10	5	8

After all material properties are given a score, it is necessary to analyse how important each property is, both for the performance and for the viability of the final component. In Table 9, it is possible to see that analysis. To each property, a score from one to five is given, being that one is the lowest score and five is the highest. This way, properties with higher relevance for the rear cover have a higher impact when choosing the material. In the final column of the table it is represented the sum of all property values of each material. The material that gets the highest score is the most recommended to use in the manufacturing of the rear cover. As gorilla glass properties are not complete (P3 and P4 are not in the spec sheet), two scores are given, one if the value of these properties was one and other if the value of this properties was ten.

Table 12 - Rear cover material selection

<table>
<tr><th></th><th colspan="2">P1</th><th colspan="2">P2</th><th colspan="2">P3</th><th colspan="2">P4</th><th colspan="2">P5</th><th colspan="2">P6</th><th>Σ</th></tr>
<tr><td>PP-TD20</td><td>8</td><td rowspan="4">5</td><td>10</td><td rowspan="4">3</td><td>5</td><td rowspan="4">4</td><td>4</td><td rowspan="4">4</td><td>2</td><td rowspan="4">3</td><td>5</td><td rowspan="4">5</td><td>137</td></tr>
<tr><td>PPS</td><td>7</td><td>6</td><td>4</td><td>10</td><td>10</td><td>10</td><td>189</td></tr>
<tr><td>PBT</td><td>8</td><td>8</td><td>10</td><td>6</td><td>5</td><td>5</td><td>168</td></tr>
<tr><td>PBT/PET</td><td>10</td><td>7</td><td>6</td><td>8</td><td>7</td><td>8</td><td>188</td></tr>
</table>

After analysing Table 12, it is possible to observe that there are two materials that can be considered to manufacture the rear cover, since their values are very close to each other. PPS and PBT/PET+GF 30 are two thermoplastics that are widely used in the mechanical industry. While PBT/PET offers a lower cost, lower density and a higher impact strength, PPS excels when it comes to tensile strength, elongation and modulus of elasticity. While both materials would be valid to use in the rear cover, PPS offers a higher glass transition temperature, temperature region where the polymer transitions from a hard, glassy material to a soft, rubbery material (Epotek, 2012), and a higher heat deflection, measure of a polymer ability to withstand a given load at high temperatures (MatWeb, 2019). Thus, as the product is to use outdoors and temperatures may vary, the choice of material is PPS, which is more temperature resistant while offering great overall specifications, in which the main downside is the cost.

3.8.6 Surface finishing

Surface finishing is used to alter or improve the specifications of a given material in order to make it more capable and more efficient in his application. When considering the product, specifically the front frame, the main surface treatments that can be used are Anti-Fingerprint Coating (AFP), Anti-Reflection treatment (AR) and Anti-Scratch treatment (AS). Although AS treatment can be used, PMMA is highly scratch resistant, so the treatment would not be necessary, and therefore not efficient. AR treatments have evolved into highly effective reflectance and glare reducing coatings that are used to optimize optical equipment. These coatings work by applying very thin layers of metal and mineral oxides on the surface. These will transmit the light trough the material instead of reflecting it. This results in an improvement of clarity and light transmission while reducing all unwanted reflections (Hemant Kumar Raut, 2011). AFP treatments are also extremely beneficial. This coating creates a barrier that prevents the intrusion of oxygen and moisture, enhancing the material anti-fingerprint abilities. Yet, since the equipment will not be touch operated, this treatment would not be necessary. If the PTW cluster would be touch operated, then this type of coating could be utilized to enhance the display properties (Mirror Metals, 2018).

In the rear cover, there are also surface finishes that can be used, treatments such as bead blasting or chemical attacks can be used to give the surface a different appearance, by removing brightness and giving texture to the material. Both these treatments can also be used to improve adhesion and higher bonding specifications when applying paint.

3.9 Adhesive

The adhesive will be laid in the back cover, which is made from PPS Ryton BR111 BL thermoplastic, produced by Solvay. According to the manufacturer, the material should be treated before the application of the adhesive. When two parts are joined, they need to provide a high strength bond in order to withstand the tensile or shear stresses the component will be involved in. To provide a strong bond, the PPS Ryton must have its contaminants removed from the surface. Therefore mechanical, flame, corona, plasma and acid treatments can be used. Contaminants act as weak boundary layers and decrease the strength of the adhesive bond (Solvay, 2015). The adhesive to be used is Semicosil 811 commercialized by Wacker Chemie AG. Semicosil 811 does not require primer when bonding most substrates, has a fast adhesion built-up at room temperature, is thixotropic, has high flexibility and high temperature resistance. As mentioned earlier the substrate must be decontaminated, cleaned and dried before the application with optional pre-treatment used. A Pt-catalyst, ELASTOSIL® CAT Pt, and a UV active catalyst, ELASTOSIL® CAT UV, are both provided and increase the reaction rates. The Semicosil 811 contains the crosslinker, which when mixed with one of the other components, will react and be prepared to act as a bonding agent. The two are mixed at a 10:1 ratio, either by weight or volume. To eliminate any air introduced during dispensing, or to prevent air entrapment between components, a vacuum de-airing process in the material supply feeding system is recommended. Semicosil will cure at room-temperature or with UV radiation, with a wavelength between 250 and 350 nm, if ELASTOCIL CAT UV is used. The curing time can range from 5 to 10 s with ultraviolet (UV) activation, or 15 to 20 min with a room temperature of 25°C, for a layer thickness up to 8 mm (Waker Chemie AG, 2015).

3.10 CAD modelling

3.10.1 Front frame

The front frame was designed as seen in Figure 44, it has a symmetrical shape with the sides smaller in comparison to the middle of the display. This way the instrument panel can fit in most motorcycle models and maintain active areas sufficient in size to provide the visual information to the user.

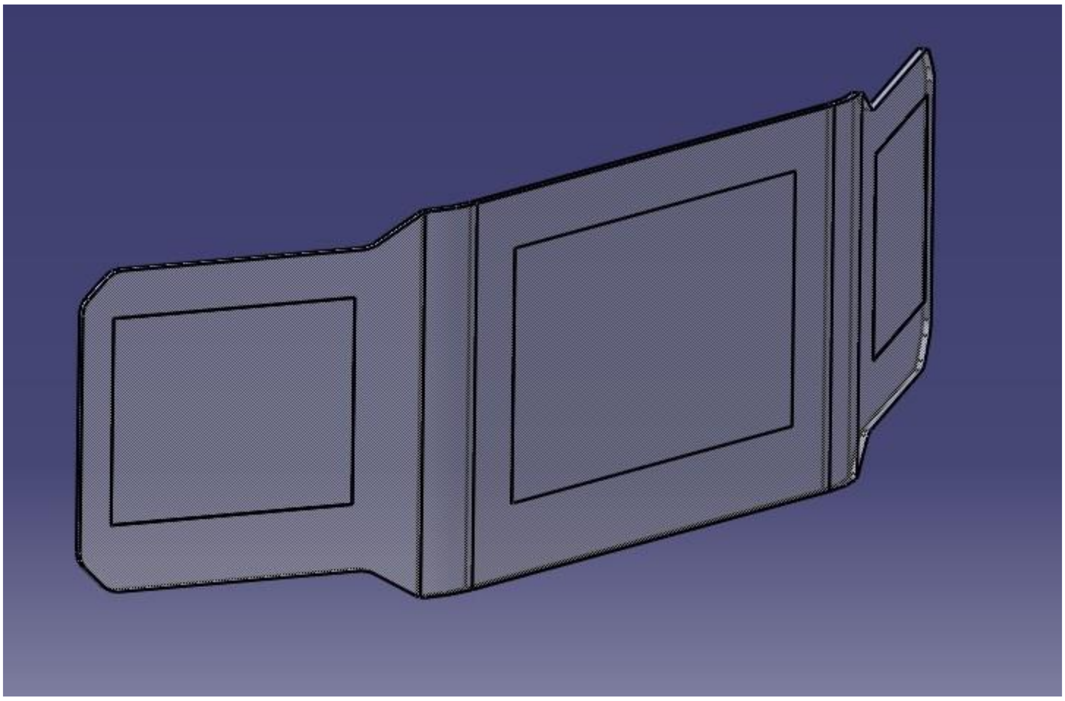


Figure 44 - Front frame

3.10.1.1 Manufacturing process

Initially, the PMMA is laminated into a 3 mm thickness sheet. After this process, the sheet can be stamped or laser cut into the desired format, with the correct unfolded dimensions, as presented in Figure 45.

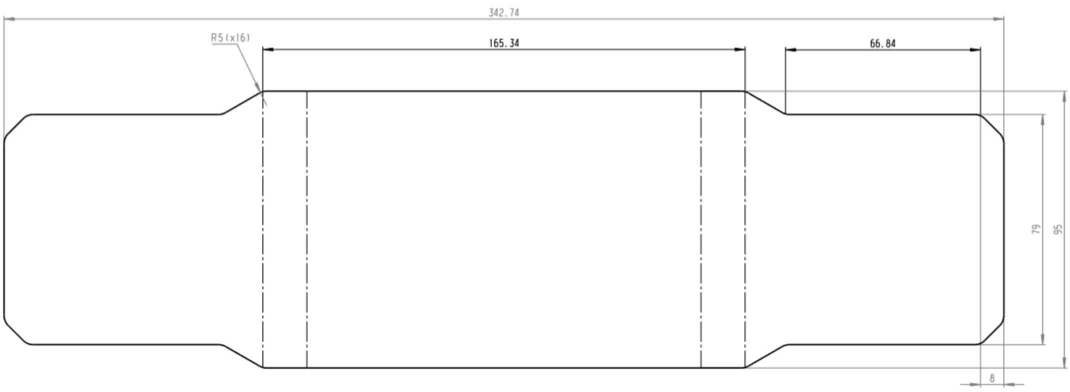


Figure 45 - Unfolded dimensions of the front frame

Since the instrument cluster utilizes a new technology, that has never been used in a production motorcycle, it is likely that it will be a payed feature in the first models. As a result, since the production and demand will be limited, the CO_2 laser cutting process is chosen as the manufacturing process for the front frame. CO_2 laser cutting, uses a focus lens to gather CO_2 laser beams on the material surface, melting the surface, which may engrave or fully cut through the material (Figure 46). This process has a very small incision width (0.1 – 0.5 mm), high precision, provides a very smooth surface roughness on the part, has a very high cutting speed and pollutes less than comparable manufacturing processes. However, it cannot compete with them, when it comes to cutting high thickness parts and cost.

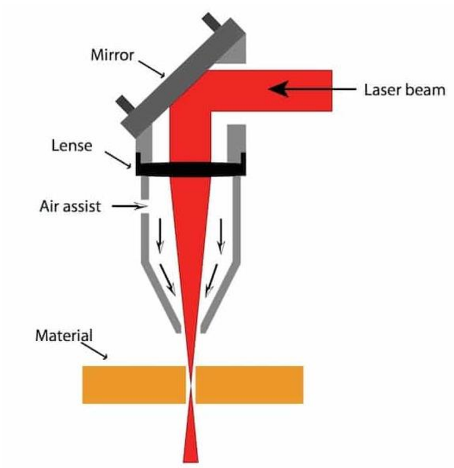


Figure 46 – CO_2 laser cutting process (MachineMfg, 2018)

After the PMMA sheet is laser cut, in order to get the desired angles in the component, the material is heat bent. This is a process in which the material is heated, in order to enable and ease deformation, while decreasing tension build-up and springback effect. After this process, the material is bent by a bending machine to the desired shape. Materials have a springback effect, which is the geometric change made to a part at the end of the forming process, when it has been released from the forces of the forming tool. In order to get the desired bend in the final product, it is necessary to over-bend the PMMA sheet. Such that, the part has the correct geometry after it suffers this phenomenon. Nowadays, this effect is detected and compensated for, by simulation software's, which make this process reliable and fast.

The material is bent in the dash dotted zone, seen in Figure 45, into the desired shape, with a 152.1° angle with the horizontal (Figure 47). The PMMA can then be treated with AFP and AR treatment if required, as previously discussed.

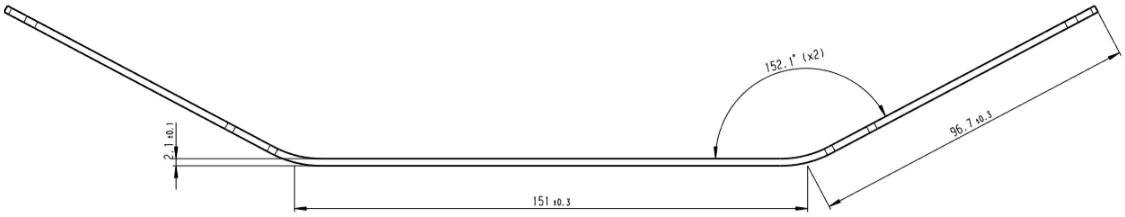


Figure 47 - Bottom view of the front frame

3.10.2 Blackprint

The blackprint is a black coloured tape or a paint that is applied to the front frame. It serves as a light blocker and defines the active area of the display. This means that the area that is not covered by blackprint is the only area that will transmit light, which is called the “active area” of the instrument panel. The blackprint has the objective of hiding all the internal components apart from the active area of the LCD, in order to provide a smooth and appealing design to the end product. The material used for this component, is a black PC film combined with an adhesive tape, as utilized in other products at Bosch (Figure 48).

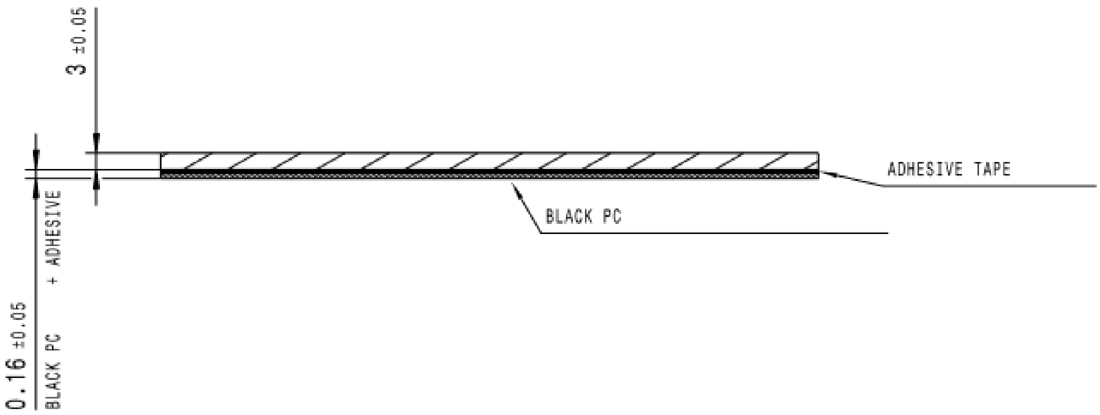


Figure 48 - Blackprint application

In Figure 49, it is possible to visualize the front frame after the blackprint has been applied.

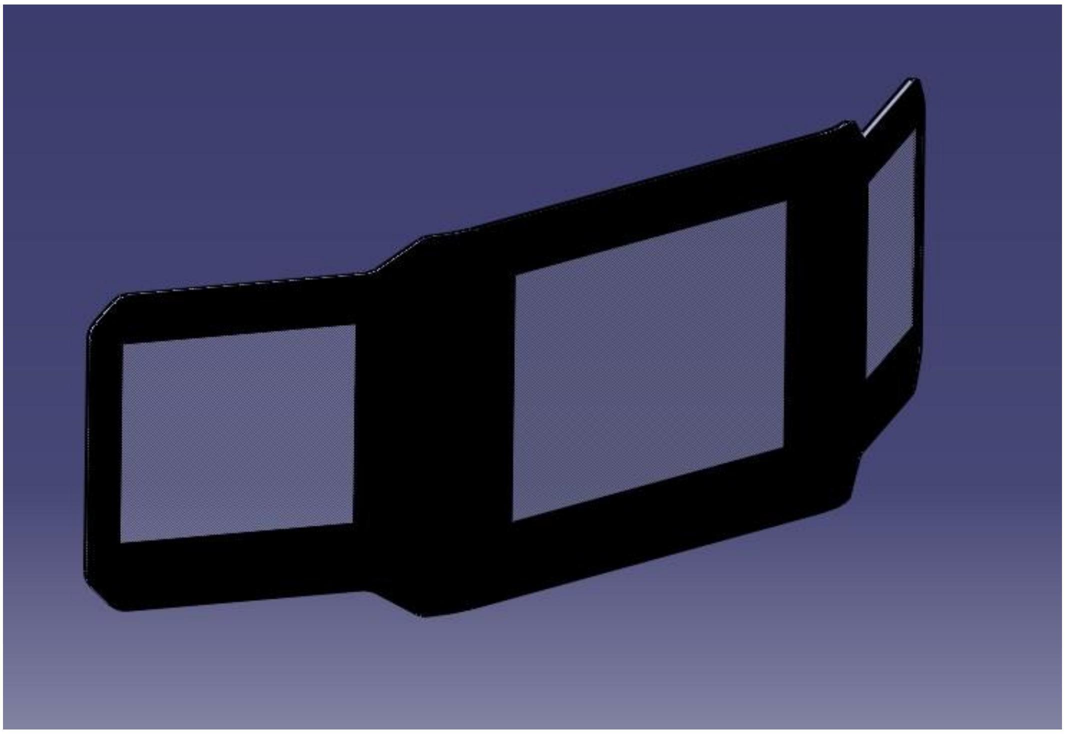


Figure 49 - Blackprint applied to the front frame

3.10.3 Rear cover

The rear cover design follows the same external layout as the front frame (Figure 50). To add structural stiffness, a honeycomb reinforcement is also utilized. It features a glue channel around its limits to allow bonding with the front frame. And it has three guiding features and three datum features to use as references during the assembly.

When possible, the rear cover was designed with a specific thickness, of 2 mm, around its entire geometry, in order to ease the injection process. Thus, reducing defects in the component, such as sink marks, warping and others, which may be caused by uneven shrinkage triggered by non-uniform cooling in the mould (Gurjeet Singh, 2017).

Other design consideration was to draft all the surfaces in the direction of the mould extraction procedure. The draft angle utilized was 2°, as seen in other similar projects at Bosch. After the component design was finalized, the CAD model was submitted to a draft analysis (Figure 51 and Figure 52), with the following specifications (Figure 53). After examining the results, it is possible to see that the analysis was successful, since the green and blue colour are separated at the component parting line. This way, the component can be successfully and easily demoulded.

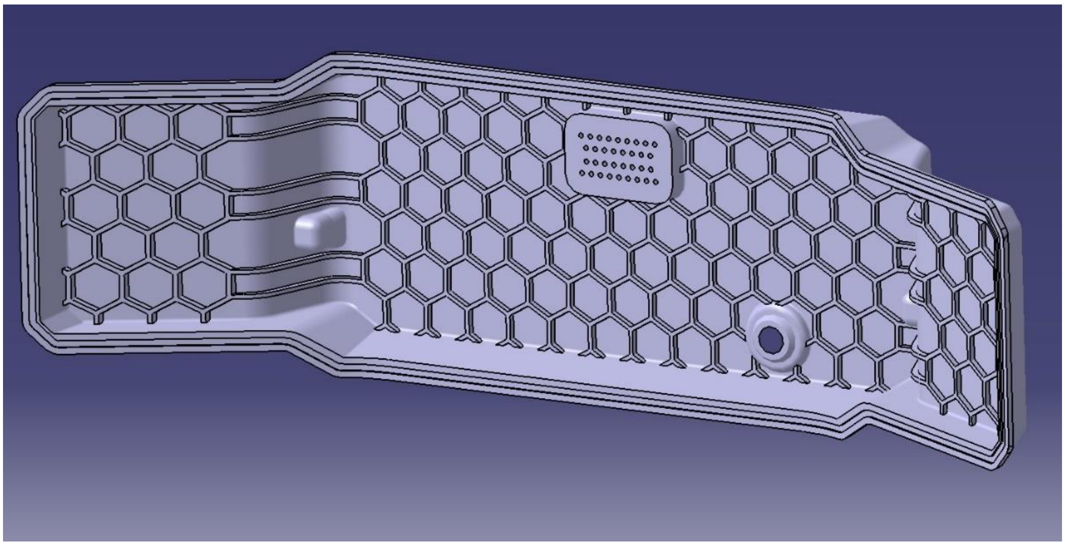


Figure 50 - View of the rear cover

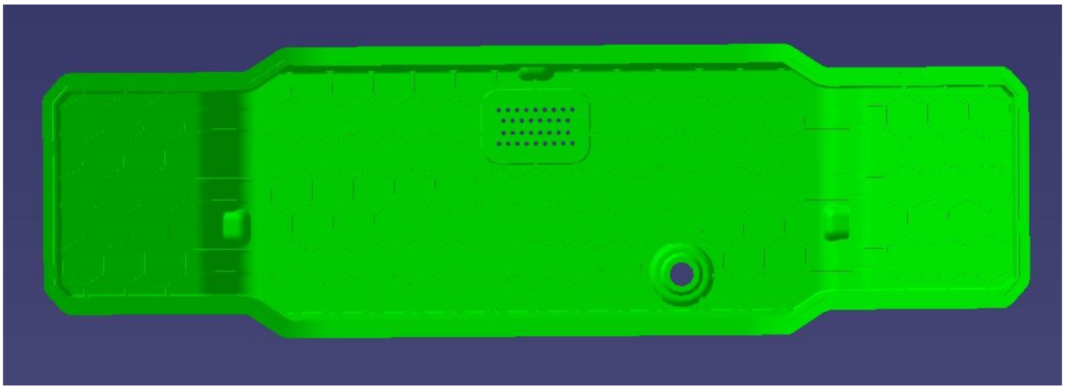


Figure 51 - Draft analysis (front view)

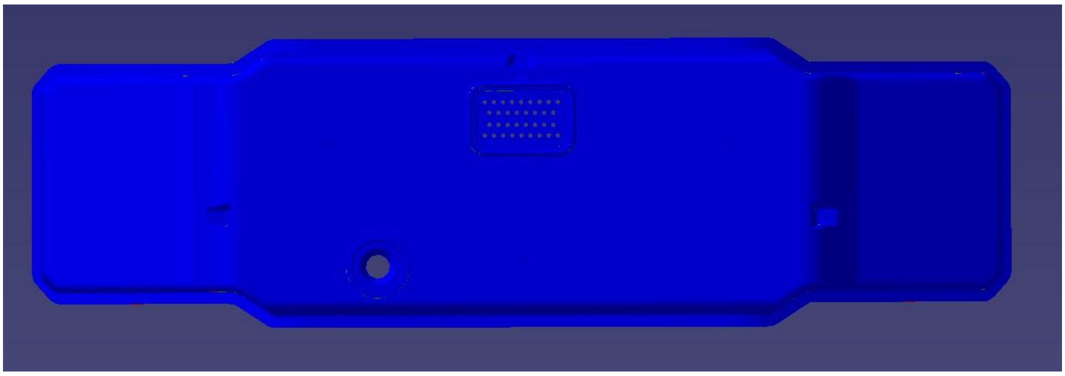


Figure 52 - Draft analysis (rear view)

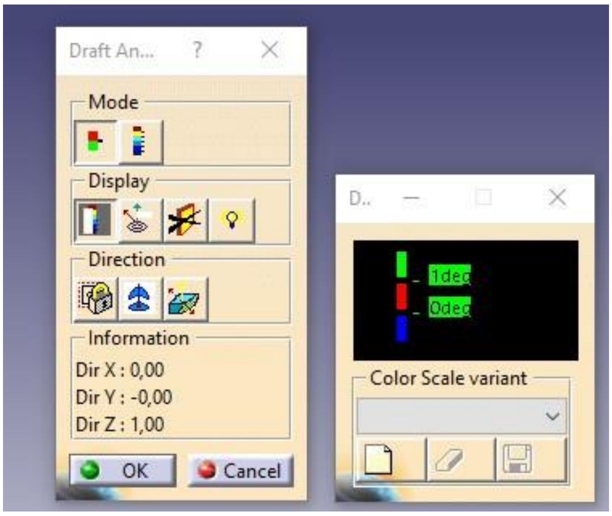


Figure 53 - Draft analysis specifications

3.10.3.1 GORE vent hole

The GORE vent hole (Figure 54), is a hole dimensioned specifically to install a GORE vent at the end of the assembly. This feature serves to accommodate this component that serves as a pressure manager preventing deformations and component failure.

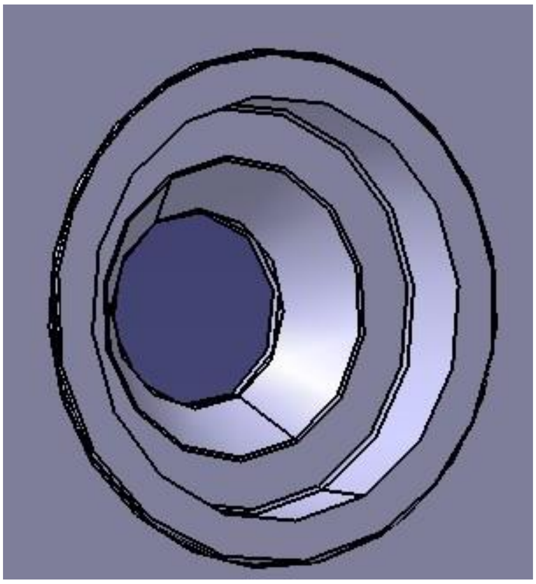


Figure 54 - GORE vent hole

3.10.3.2 Connector feature

A connector silhouette feature is included in the rear cover (Figure 55). This feature is present, in order to, both guide the rear cover into the correct position against the connector pins in the PCB, and to allow the PCB to be powered through to an external battery. This, while still sealing the assembly from dust, moisture and water, present in the surrounding environment.

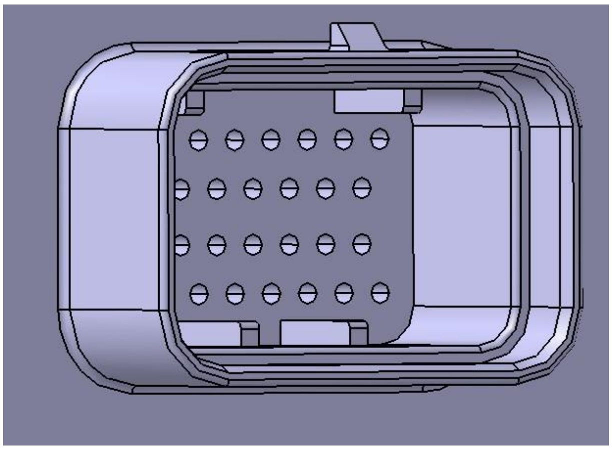


Figure 55 - Connector feature

3.10.3.3 Adhesive channel

The adhesive channel is present around the shape of the rear cover, this channel is 0.6 mm deep and 2 mm wide, as used in other similar projects at Bosch. The adhesive must be laid in the totality of the channel, in order to promote a strong bond between the joined components.

3.10.3.4 Datum and guiding references

Three saliences and three guiding inserts were adapted to the rear cover. Their purpose was to allow the component to be successfully mounted and assembled against the front frame.

In order to accurately take the measurements of the rear cover and to correctly position the component in space, a coordinate-measuring machine (CMM) is utilized. A CMM is a device that measures the geometry of a physical object by sensing discrete points on its surface with a probe. The points and features utilized in this component as reference are seen in Figure 56.

The reference entities can be points, lines or planes and there is always three of them. Thus, datum references are used to lock the component in space. The probe can have different shapes and the one utilized in the rear cover is spherical, since it uses the same contact point every time, when taking a measurement.

It is possible to see in Figure 56 the three datum references that will be used. Number 1 are three saliences that will form a plane, number 2 are two guiding features that will form a line, and number 3 is a guiding feature that will form a dot (Figure 56). To correctly join the rear cover and the front frame after all the internal components are assembled, a correct spatial positioning between the two components is necessary. This allows the components to be correctly aligned and isolated.

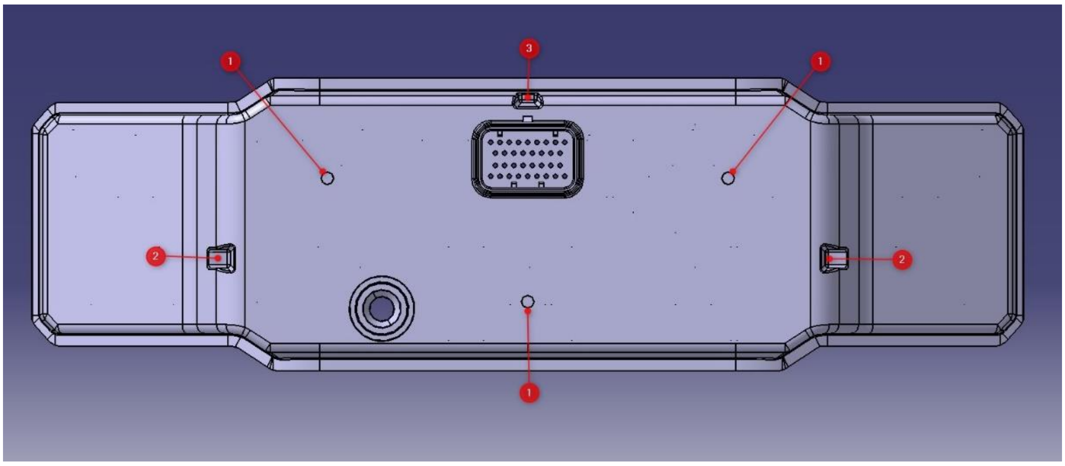


Figure 56 - Datum references

First, an operator will position the rear cover in the CMM and manually insert the locations of the centre of the three reference points seen in Figure 57.

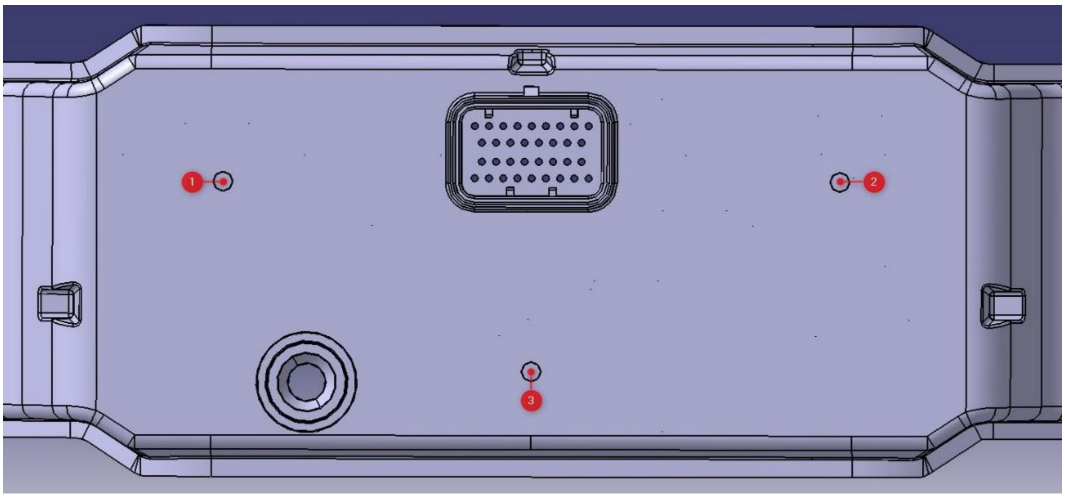


Figure 57 - First datum reference (plane)

These points will create a plane, parallel to the surface (represented by the red line in Figure 58) that will lock the component in three degrees of spatial freedom.

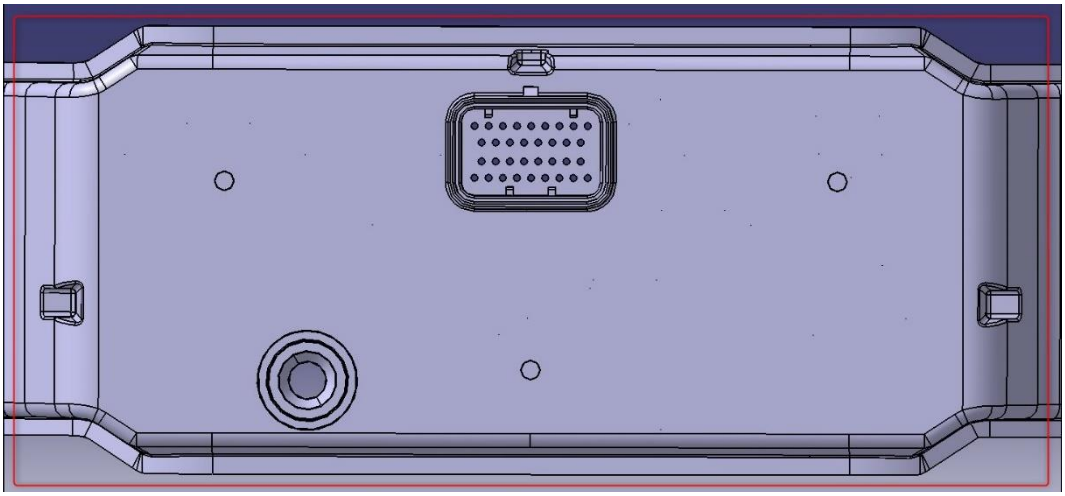


Figure 58 -Plane created by the first datum reference

After this process, the operator will manually insert the locations of the two points represented by the number 2, seen in Figure 56.These will form a line that will lock two additional degrees of spatial freedom. For the measurement to be correct and comparable with different measuring procedures, the probe will scan the feature in three different points (Figure 59). These happens because these are guiding features, and their geometry is more complex. Thus, in order to achieve a similar result in different measurements, a specific point of the feature is be considered.

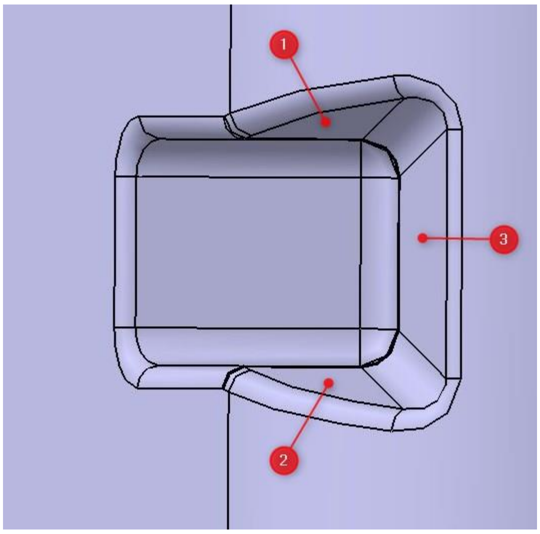


Figure 59 - Lateral guiding feature measure points

By doing so, the CMM will generate the average point between “1” and”2” (Figure 59). Then it will scan the point “3”, and connect the resulting point, forming a line, to the same average point from the feature on the other side of the rear cover (Figure 60).

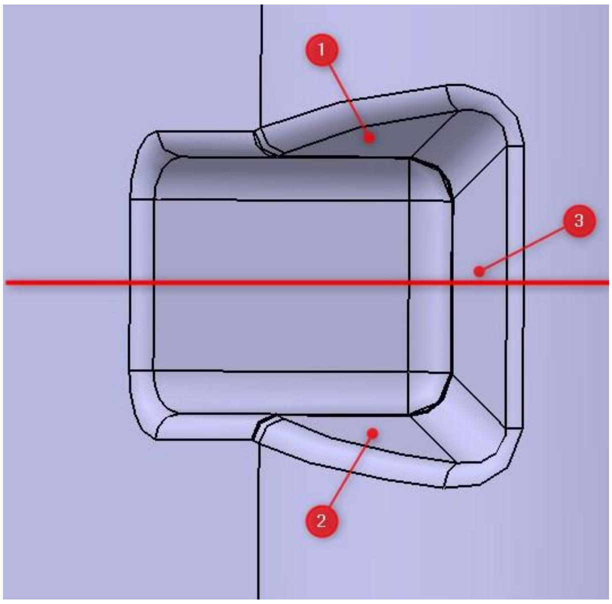


Figure 60 - Line formed by the second datum reference

After this line is created, it will lock two additional degrees of spatial freedom of the component. In order to lock the component’s final degree of spatial freedom, the operator will insert the coordinates of the final point. This point will be processed and scanned in the same way the previous two guiding features were. There are three points to be scanned by the probe, “1”, “2” and “3” (Figure 61), which will originate a single point. This point will originate a line that will intersect perpendicularly the previously created line. In Figure 62, is possible to see all the three datum references represented.

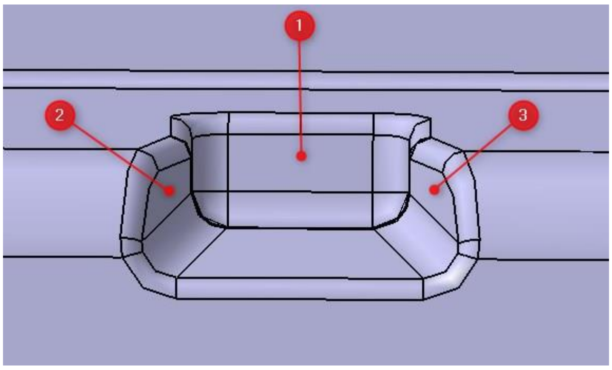


Figure 61 – Top guiding feature reference points

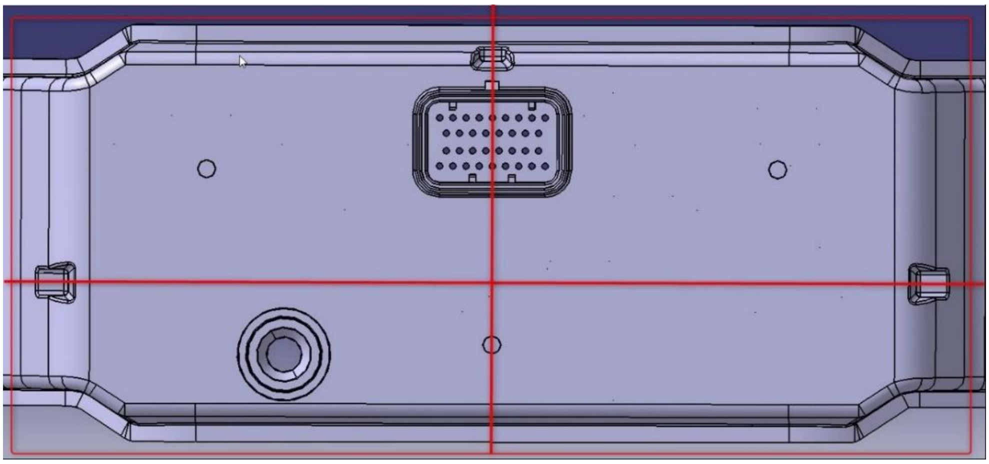


Figure 62 - Representation of the three datum references

This procedure will take place several times, until the part data and measurements are successfully processed and approved to be assembled. For the part to be approved it must respect the measurements present in the part's technical draw.

3.10.3.5 Manufacturing process

As mentioned earlier, PPS Solvay Ryton BR111 will be used as the material of the rear cover in the instrument panel. The chosen process to manufacture this component is injection moulding. In injection moulding, the material is fed by a screw-type plunger and is heated in a chamber. With temperatures rising, the material melts and it is injected into a mould through a nozzle. When the entire mould is filled with the molten material, it closes and starts to decrease the temperature in its interior. As the temperature of the material is reduced, it starts to solidify. When the material is completely solid, the mould is opened, and the component is removed, Figure 63 (Gross, 2018).

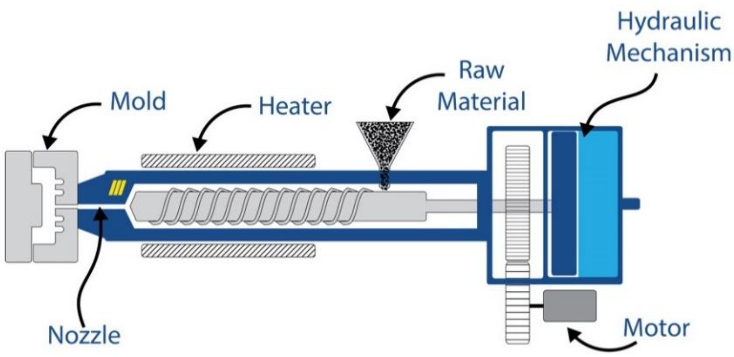


Figure 63 - Injection moulding machine (Gross, 2018)

Injection moulding can be made with a cold or a heated mould. The latter is called “hot moulding”. For the material that is going to be used, hot moulding is recommended by the supplier. This process eliminates most of the shrinkage that happens in moulding injection and allows the component to have the best mechanical properties, especially when the part is exposed to stresses at temperatures above the glass transition temperature (Solvay, 2015).

Is it recommended by the supplier that (Specs, 2019):

Material drying: Dry at 135 - 149 °C for 2 - 4 hours prior to processing.

Stock temperature: It is recommended that the injection temperature should be between 316 – 329°C.

Mould temperature: For a crystalline part, the mould temperature needs to be at 135 - 149°C, and it is best controlled by using circulated hot oil.

Back Pressure: The pressure should be between 3.5 – 7.0 bar

Screw Speed: The speed at which the screw will rotate should be 100 rpm

Injection speed: A medium to fast fill speed should work well, depending on wall thickness. The typical fill time is in the range of 0.5 to 2.0 seconds for small to medium sized parts.

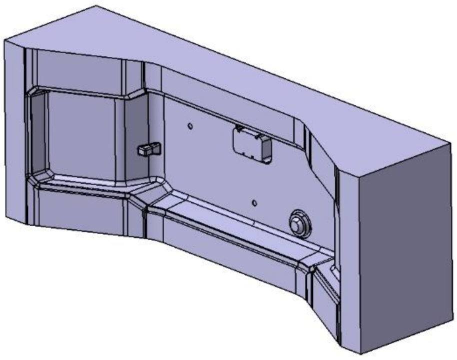
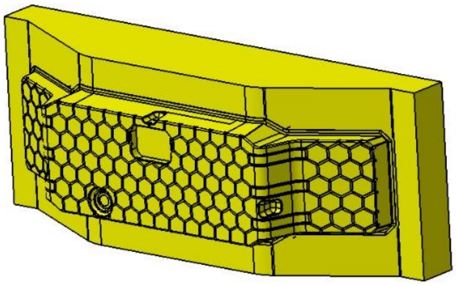
Cooling time: Usually longer cooling times are required for Ryton® PPS compounds because of the hotter mould temperatures that are utilized. Most of the time 15 to 30 seconds is adequate for small to medium sized parts, with 30 seconds to a minute, or more, for larger or thicker walled parts.

The equipment should satisfy the following requirements (Specs, 2019):

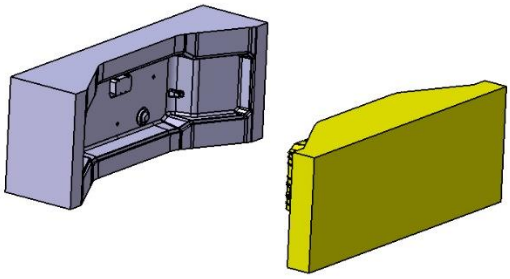
- Abrasion resistant barrel (Xaloy 801);
- Screw plunger with 16:1 to 20:1 L/D and 2.5:1 compression Ratio;
- hardened flights (Stellite or Colmonoy 6);
- Reverse taper nozzle with shot size of 25 – 75%;
- Mould steel with Rockwell hardness equal or superior to 60 HRC;
- Clamping force of 2.5 – 4.0 tons/in².

The mould in which the rear cover will be manufactured should have the geometry seen in Table 13. It is important to remember that there are features required in the mould, such as guiding features, cooling channels, tooling amongst others which are not represented.

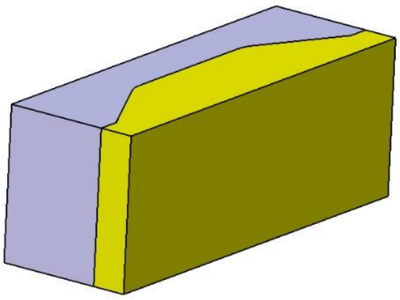
Table 13 - Back cover injection moulding

Name	Figure
Mould back part	
Mould front part	

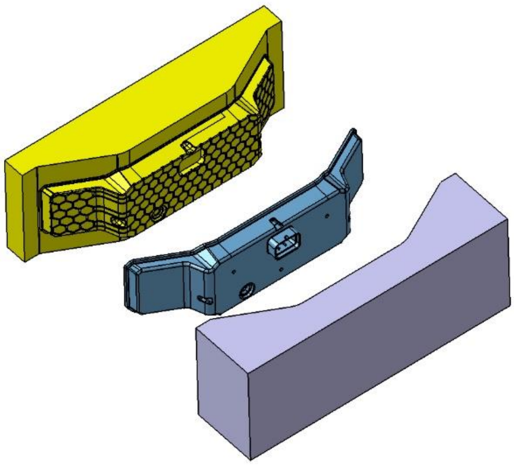
Mould front and rear parts, are aligned and ready to be joined



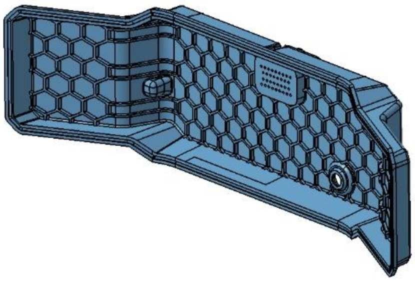
After being connected, the molten plastic is injected into the mould, and let to cool down and solidify



Moulding assembly is opened and the final injected component is removed (blue).



Injected component



Features such as the holes for the connector pins and gore plug hole, are made posteriorly to the injection moulding. To include these features in the mould would not be efficient for the operation, since they can increase the cost, decrease mould life cycle and add complexity to the process. The final component is presented in Figure 64, Figure 65, Figure 66, Figure 67 and Figure 68.

In Figure 64 it is possible to see the honeycomb structure that was designed to add structural resistance to the component. In the curved areas of the component, the honeycomb structure transforms into straight lines and then into honeycomb again. This happens, in order to facilitate and decrease the complexity of the injection moulding process.

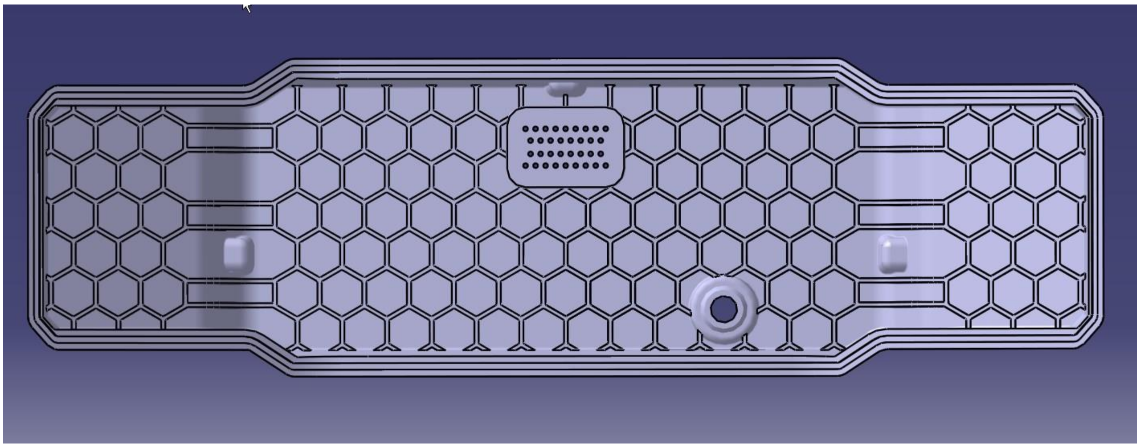


Figure 64 - Front view (rear cover)

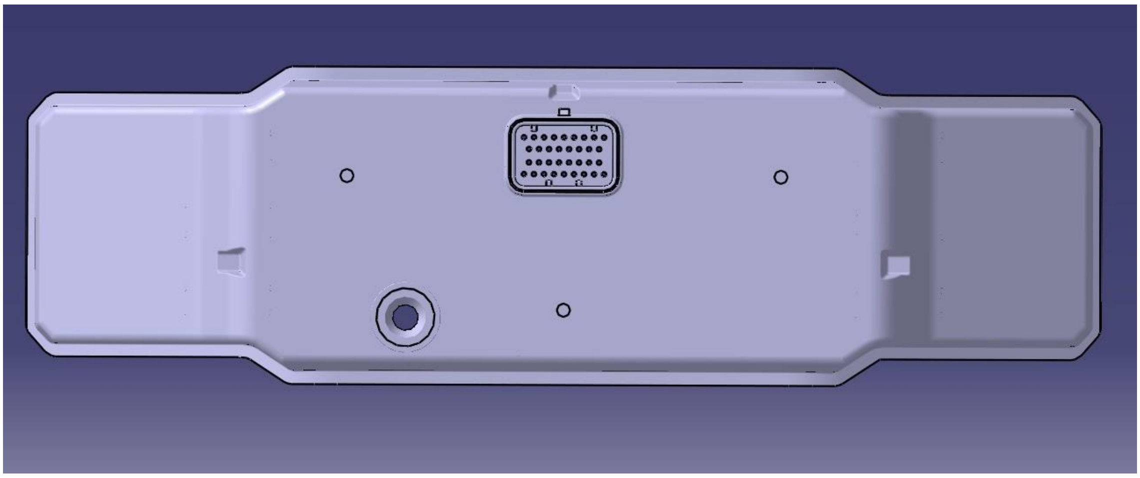


Figure 65 - Rear view (rear cover)

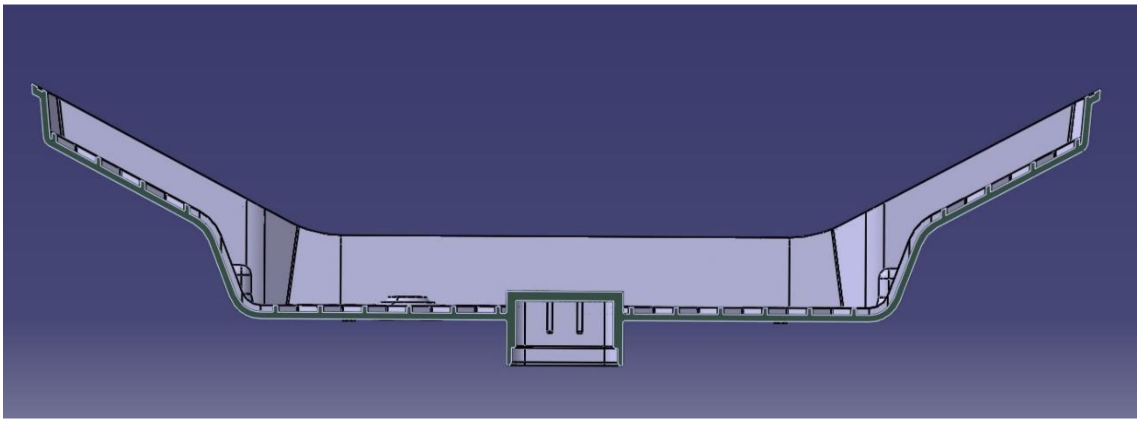


Figure 66 - Section bottom view (rear cover)

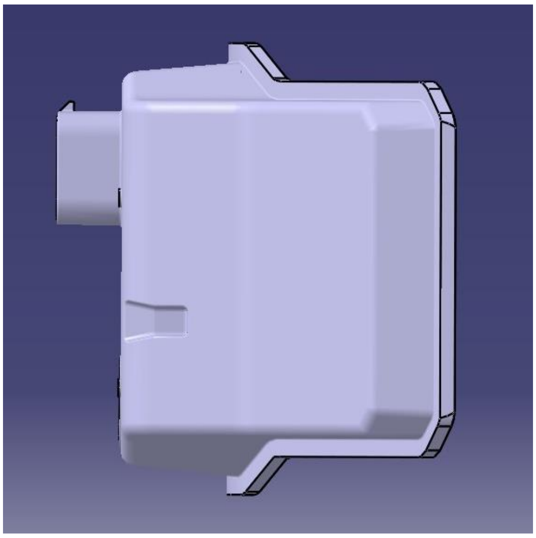


Figure 67 - Left view (rear cover)

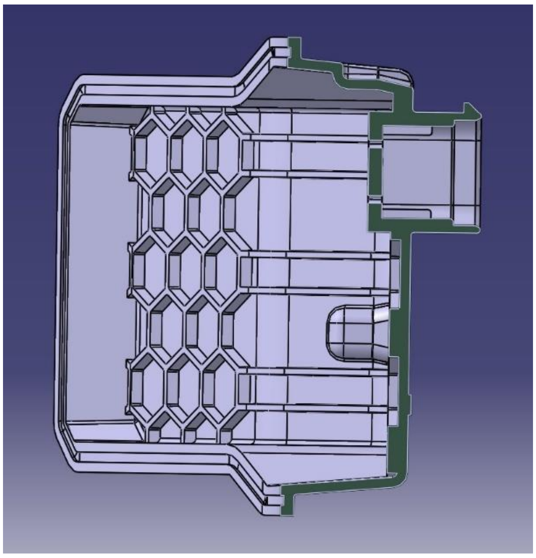


Figure 68 – Section right view (rear cover)

3.10.4 Main display and FFC

The main TFT LCD display utilized in the instrument panel is used in other products at Bosch. It is supplied as seen below in Figure 69 and Figure 70, with the required screwing holes (for M2.5X6 screws), and the FFC that will allow the connection with the PCB.

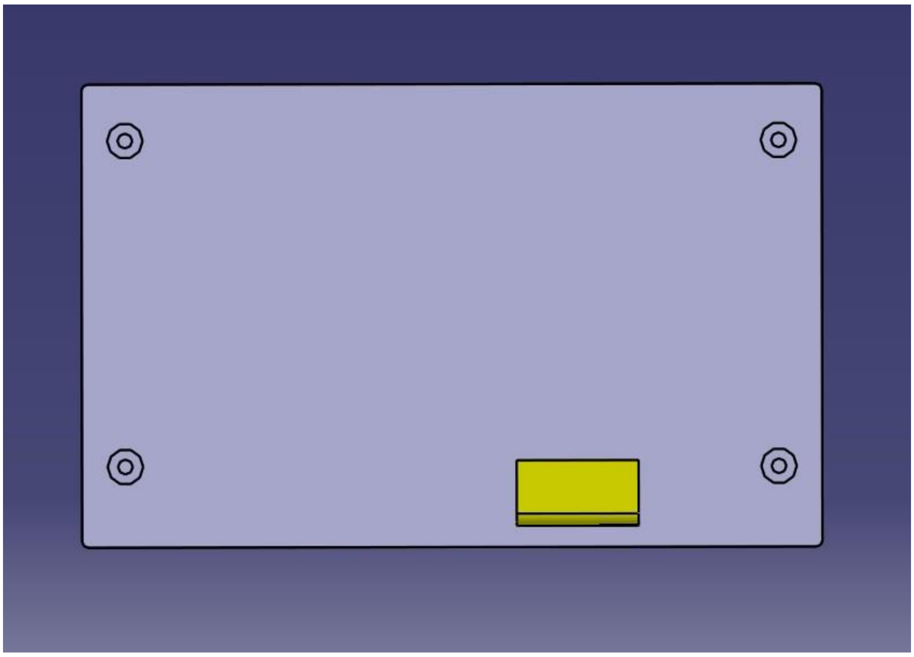


Figure 69 - Rear view main LCD

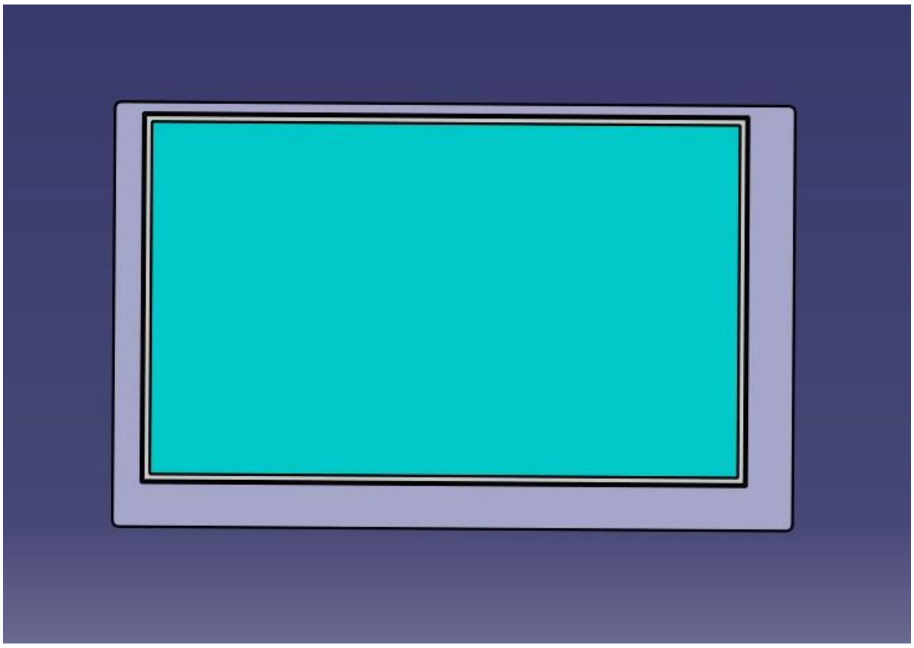


Figure 70 - Front view main LCD

3.10.5 Side Display and FFC

The side displays utilized in this instrument panel are also utilized in other Bosch products. Similar to the main LCD they are supplied with the FFC to connect with the PCB (Figure 71 and Figure 72).

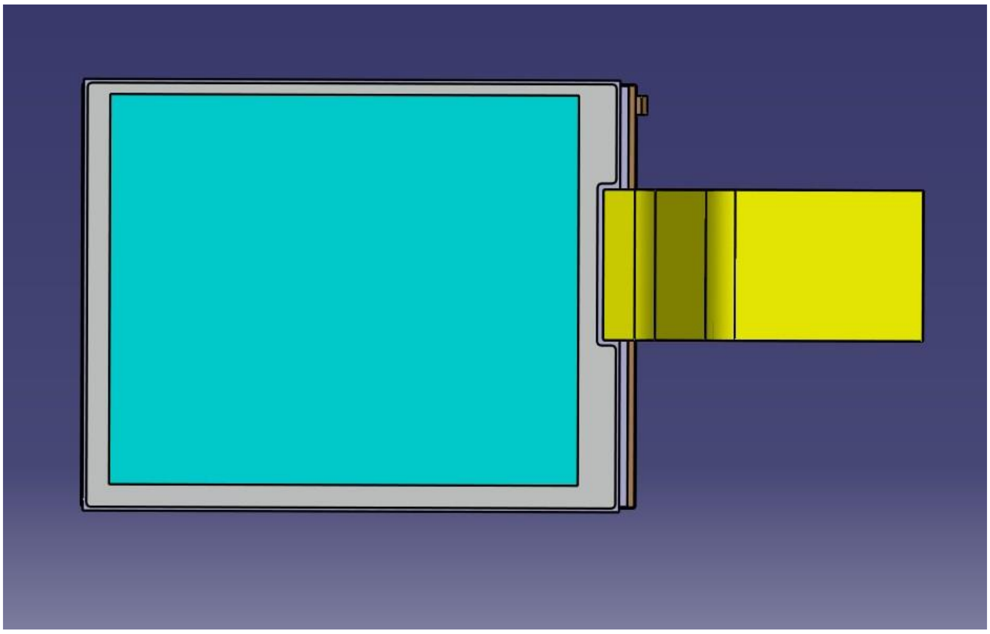


Figure 71 - Front view side display

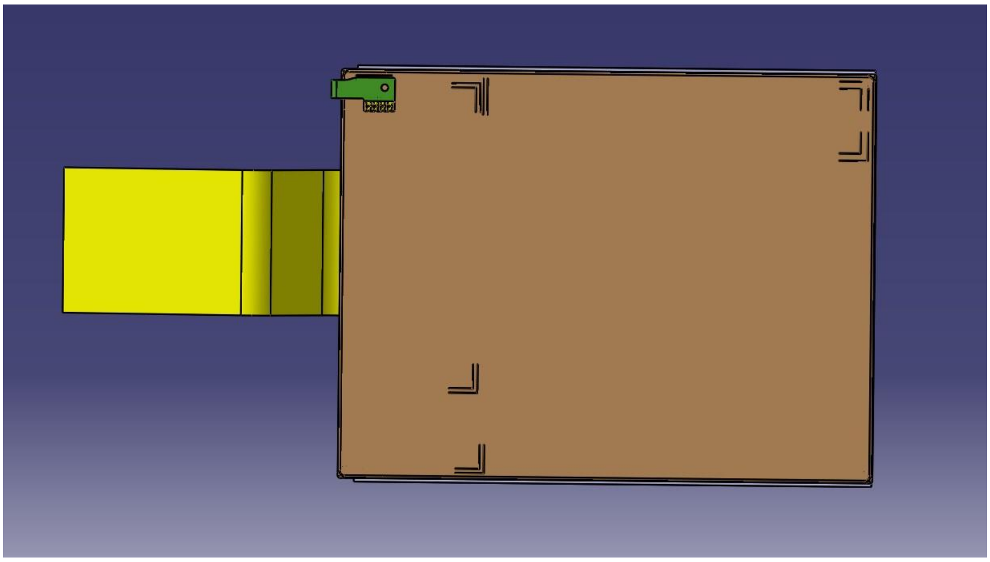


Figure 72 - Rear view side LCD

PCB

The PCB design and format is planned in order to work with the assembly. The PCB is developed in order to operate the instrument panel. It has the connector insert pins for the connector, and screw holes to attach the PCB to the front display (Figure 73).

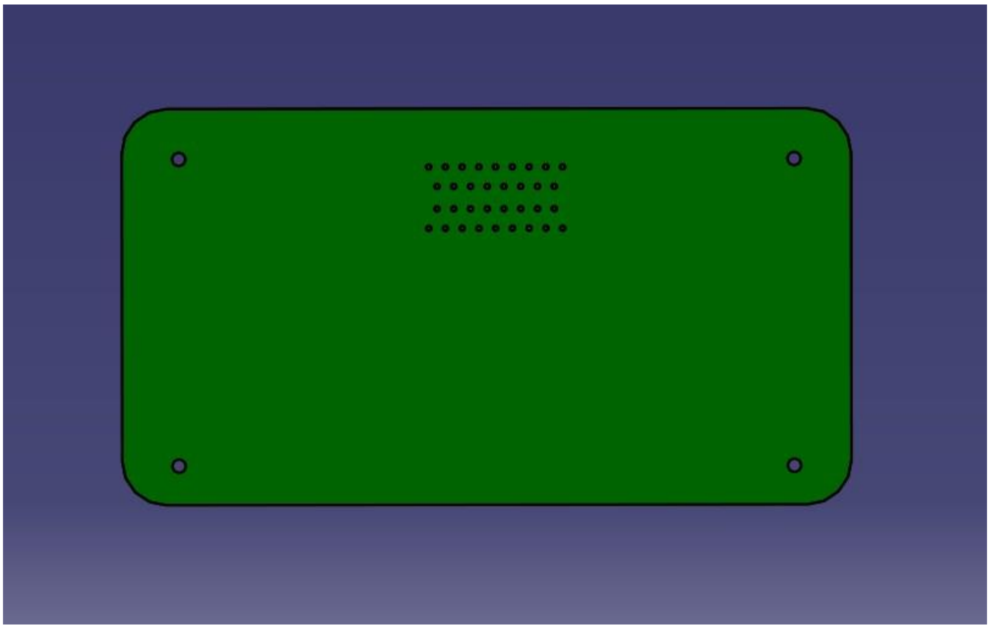


Figure 73 - Front view PCB

3.10.6 PCB connector

The PCB connector, Figure 74, utilized in the instrument panel is used in other products at Bosch. It is supplied as seen below, and it will allow the powering of the entire instrument panel. The connector pins will pass through the holes in the rear cover, Figure 75.

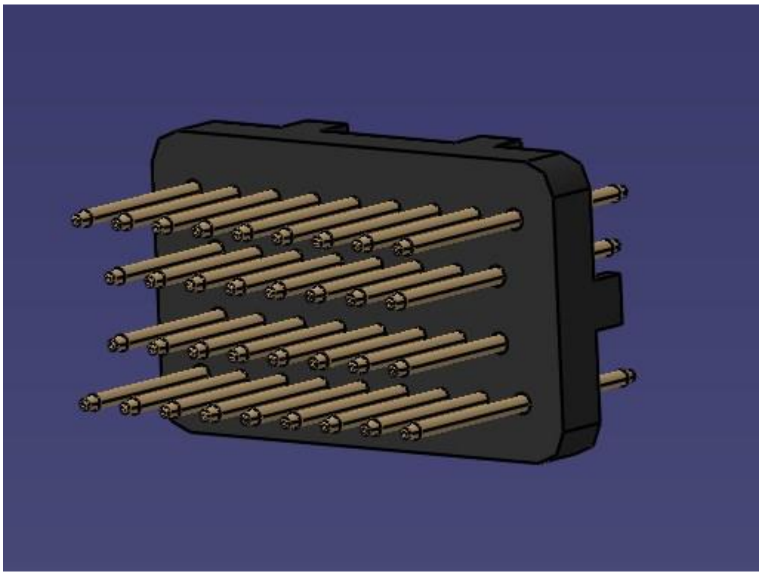


Figure 74 –PCB connector

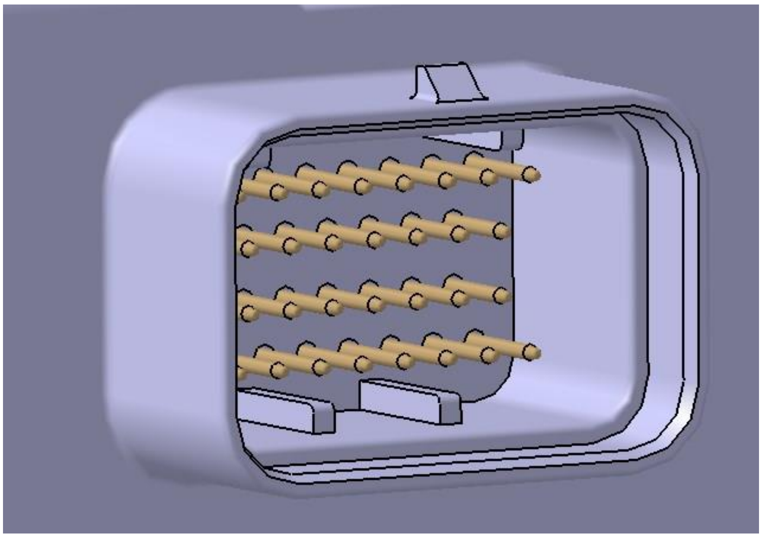


Figure 75 - PCB conector assembly

3.10.7 FFC connector

The FFC connector, similarly to the PCB connector is other product that is utilized in other projects at Bosch. It is supplied as seen in Figure 76, and will allow to connect the PCB (green) to the side LCD's, with a FFC (yellow), Figure 77.

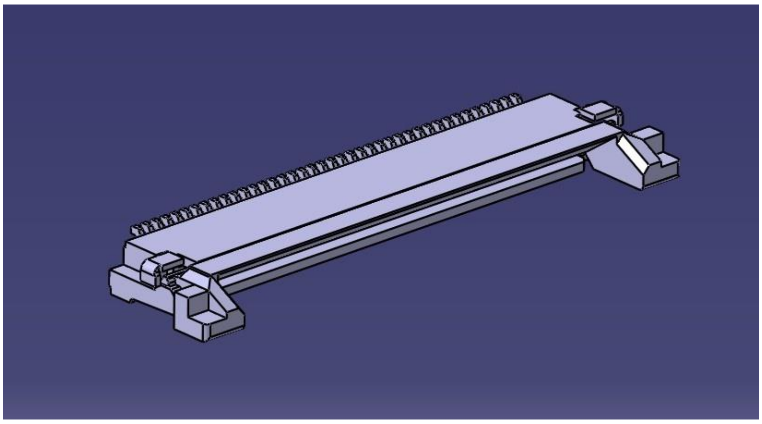


Figure 76 –FFC connector

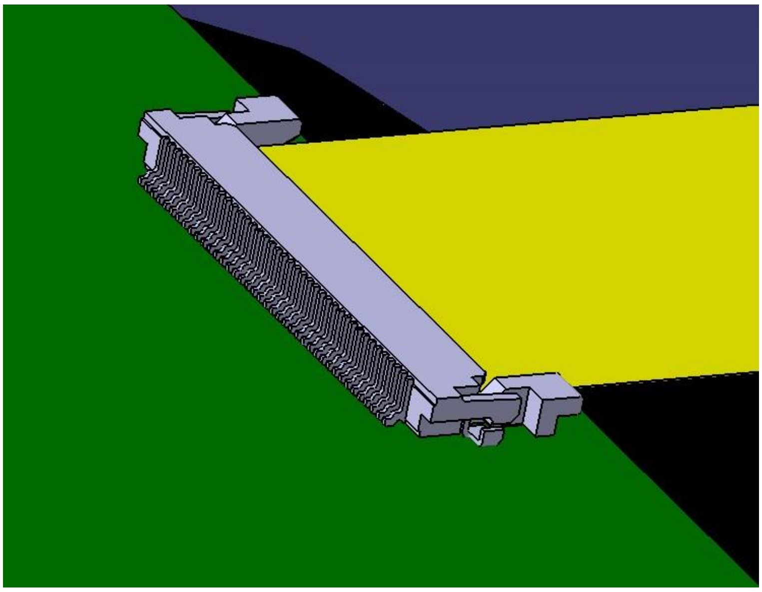


Figure 77 - FFC connector assembly

3.10.8 Gore-Tex plug

The GORE vent is supplied as seen in Figure 78, and it is used in similar products at Bosch. The vent will be inserted in the GORE vent hole, Figure 79.

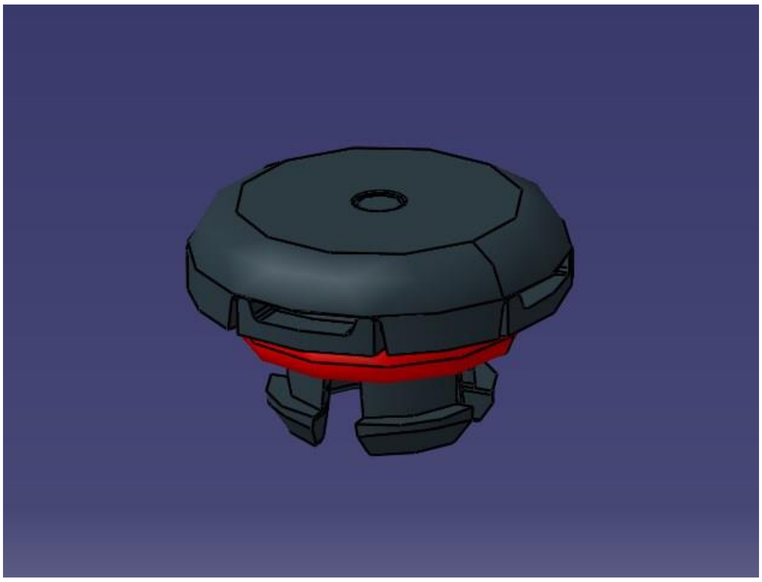


Figure 78 - GORE vent

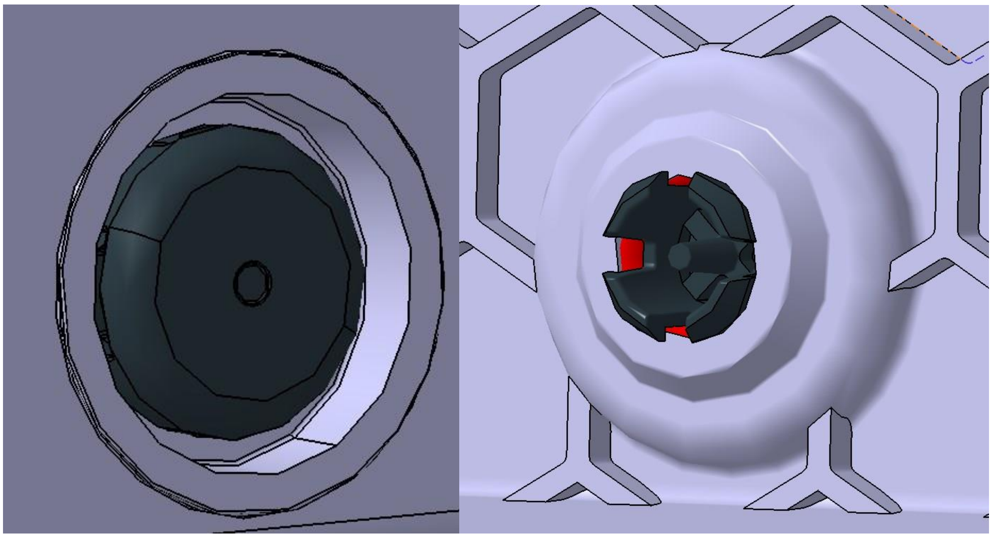


Figure 79 - GORE vent assembled in the rear cover

3.10.9 Screw

The screws utilized in order to attach the PCB to the main LCD, are M2.5X6 thread slot screws (Figure 80) provided by a Bosch supplier. The technical draw provided by the supplier is seen in Figure 81.

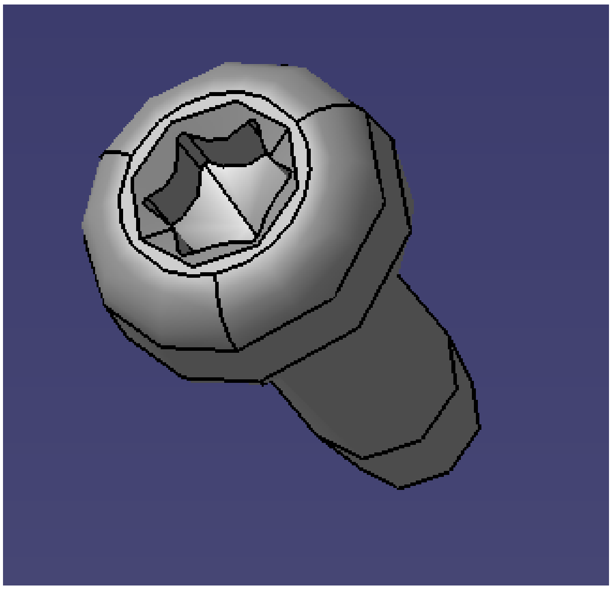


Figure 80 - M2.5X6 screw

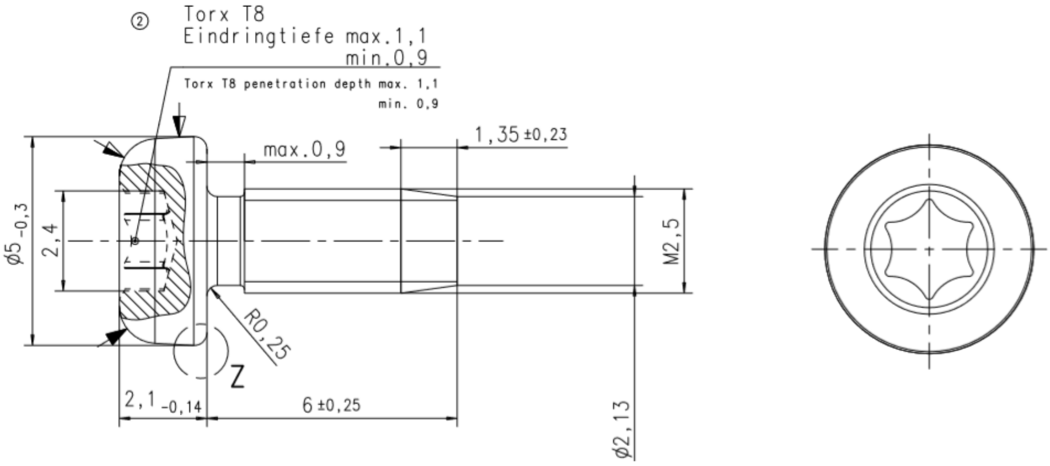


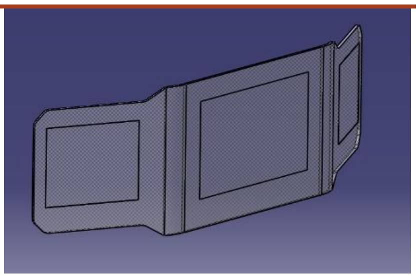
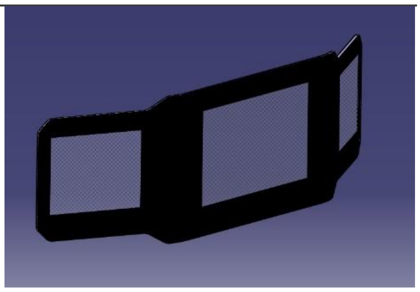
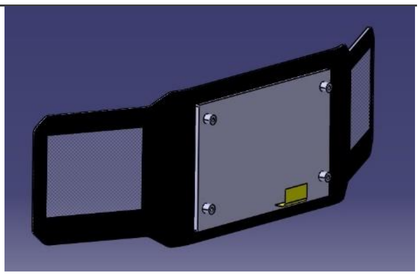
Figure 81 --- M2.5X6 screw technical draw

3.11 Assembly

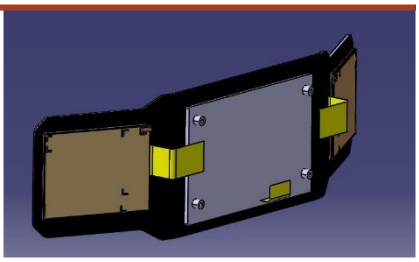
The assembly sequence takes place after all the components are manufactured. The sequence is explained in

Table 14. The LCDs are joined to the front frame with the use of optical bonding. This is an adhesive specifically utilized in LCD applications at Bosch.

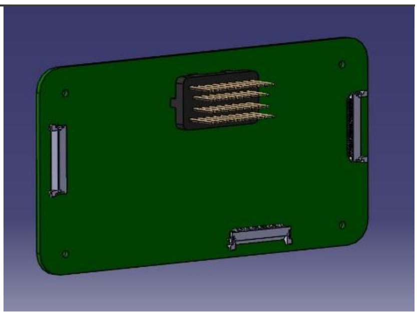
Table 14 - Assembly sequence

Step/ Description	Image
1 – Initially the front frame is provided after being laser cut and heat bent into the desired shape	
2 – The blackprint is applied to the front frame, leaving only the LCDs active areas clear.	
3 – The main LCD is assembled into the front frame using optical bonding (joining process used at Bosch).	

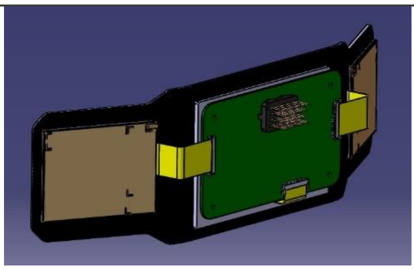
4 - The side LCD's are assembled using the same optical bonding joining procedure.



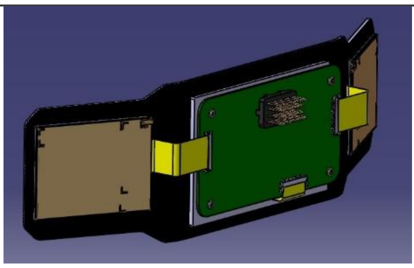
5 - The main connector and FFC connectors are mounted into the PCB



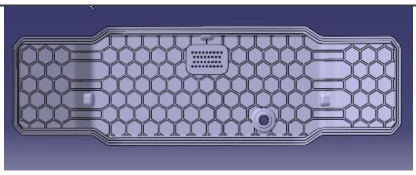
6 – The FFC's are connected to the PCB assembly connectors



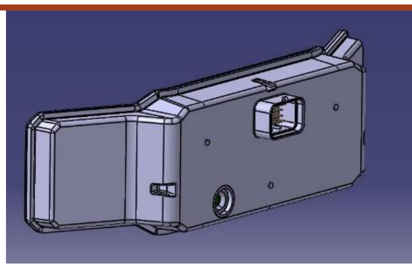
7 - The PCB assembly is mounted to the main LCD using 4 M2.5X6 screws



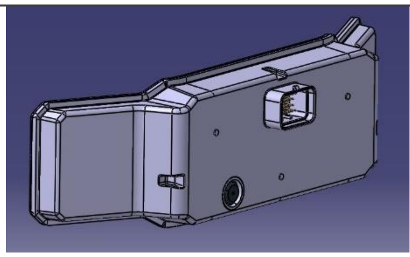
8 - Semicosil is laid up on the adhesive channel



9 – The back cover is installed on the front cover assembly



10 – Finally the GORE vent is mounted, completely sealing the final product



In the Figure 82 is possible to see an exploded view render of the complete assembly.

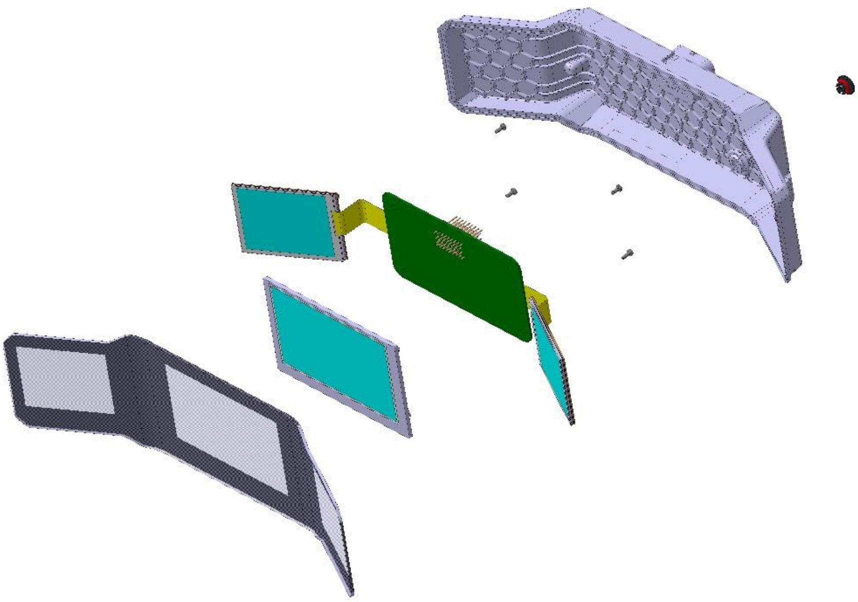


Figure 82 – Complete assembly render

3.12 Technical drawings

The technical drawings of the developed components and the assembly are presented below. The PCB technical draw is presented in Figure 83.

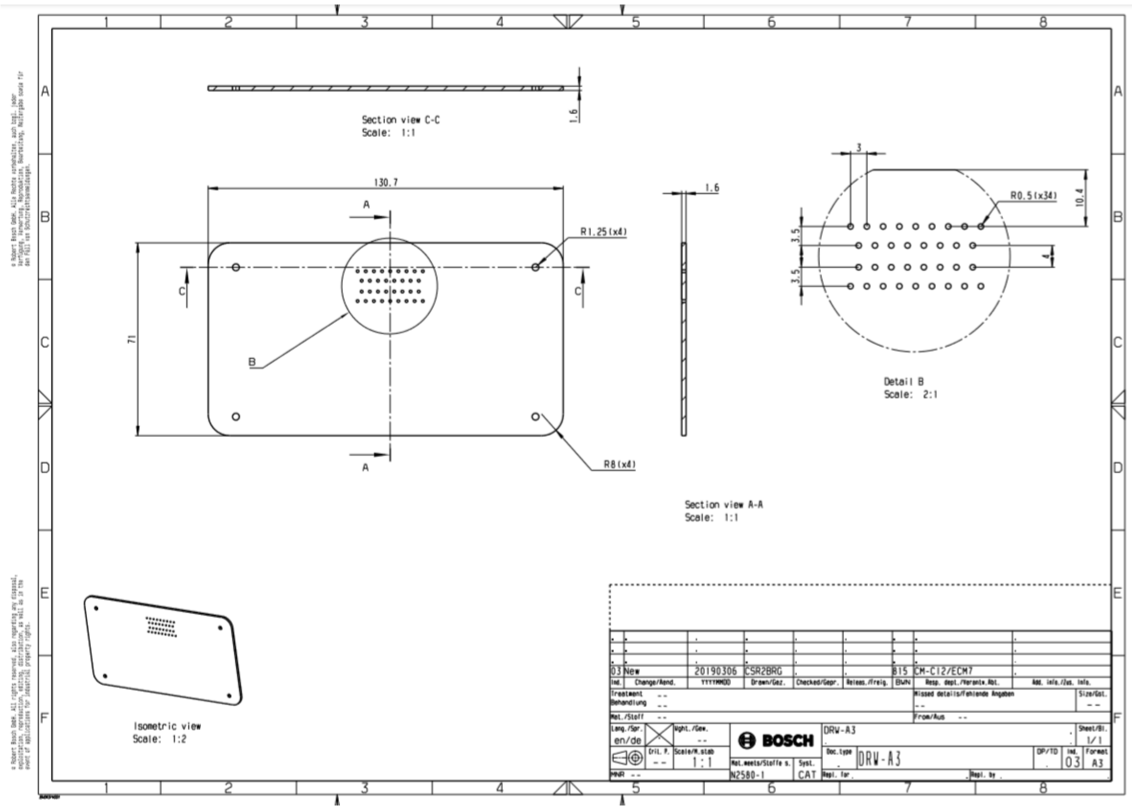


Figure 83 - PCB technical draw

In Figure 84 is presented the front frame technical draw, both the front frame and blackprint are represented.

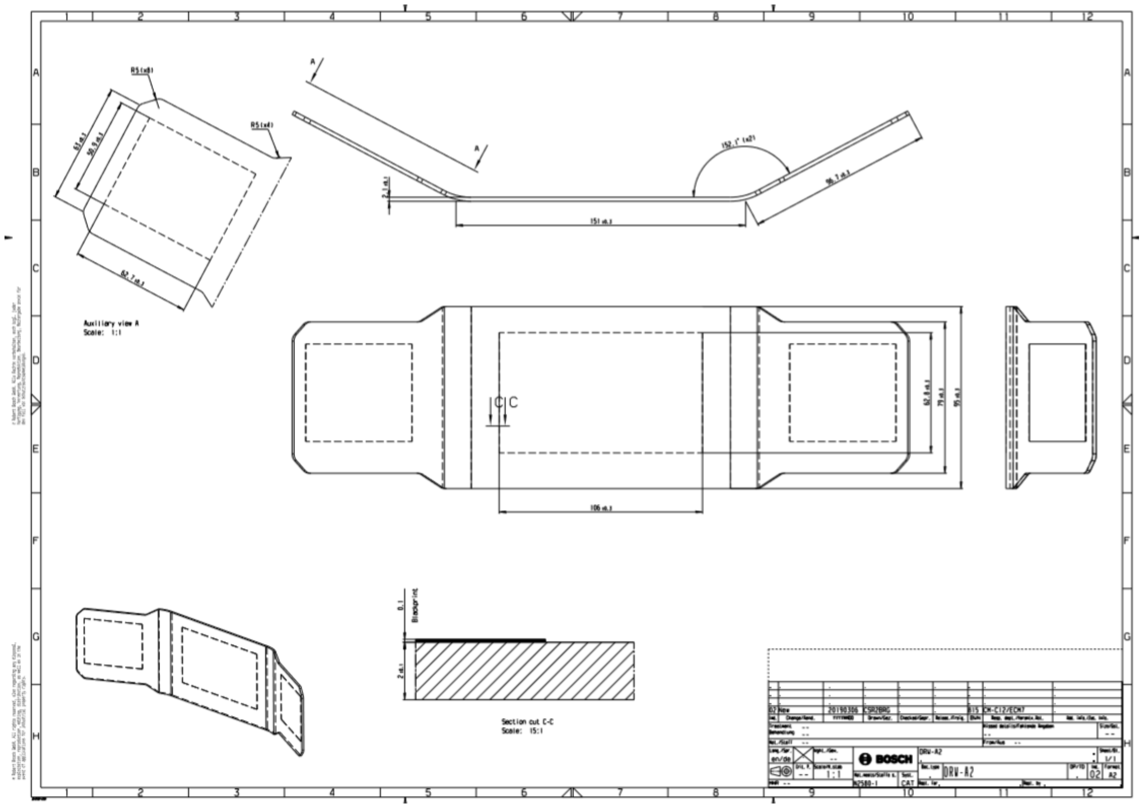


Figure 84 - Front frame technical draw

In Figure 85 the rear cover technical draw is presented. As this component will be measured and scanned by the CMM machine, the datum references are represented by the letters A, B and C. In the right side of the sheet is possible to see a table, which references the chosen points (number one to thirty-six), with the datum's (A,B and C), while considering respective tolerances. If the measurements between the points and the datum references respect the values in the table, it means the component is approved to be assembled.

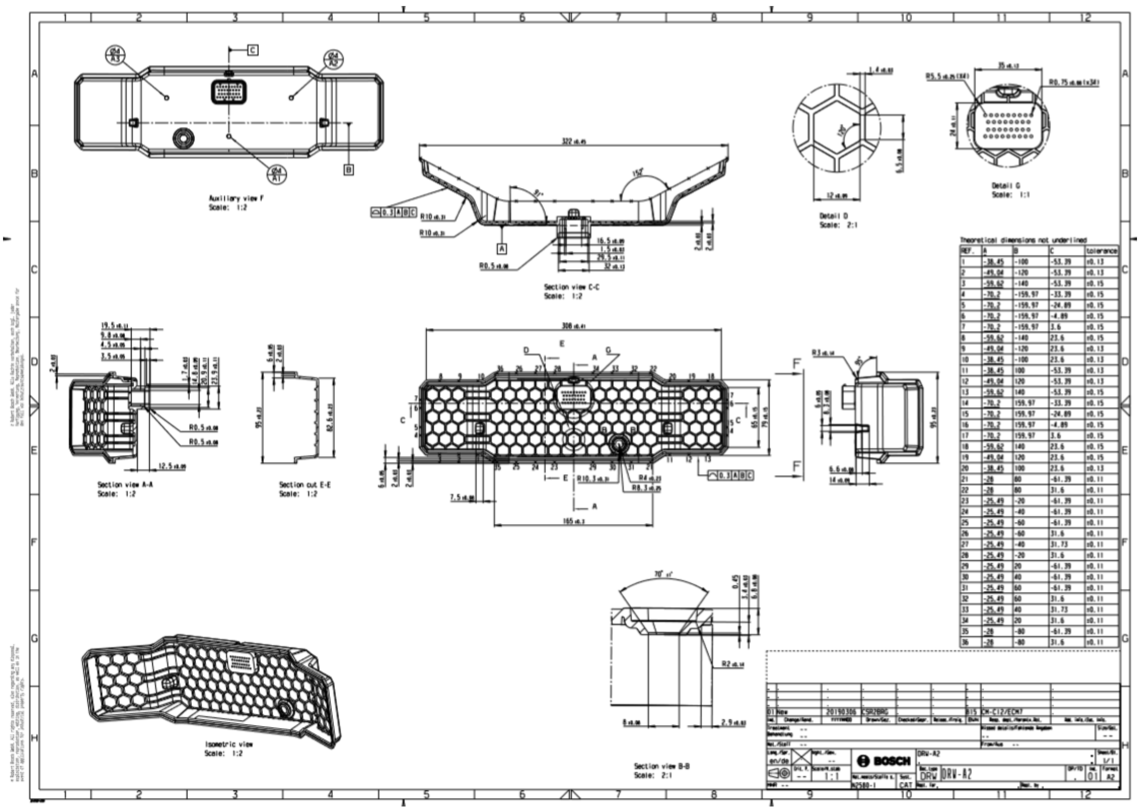


Figure 85 - Rear cover technical draw

In Figure 86 it is represented the technical draw of the final assembly with some considerations regarding it.

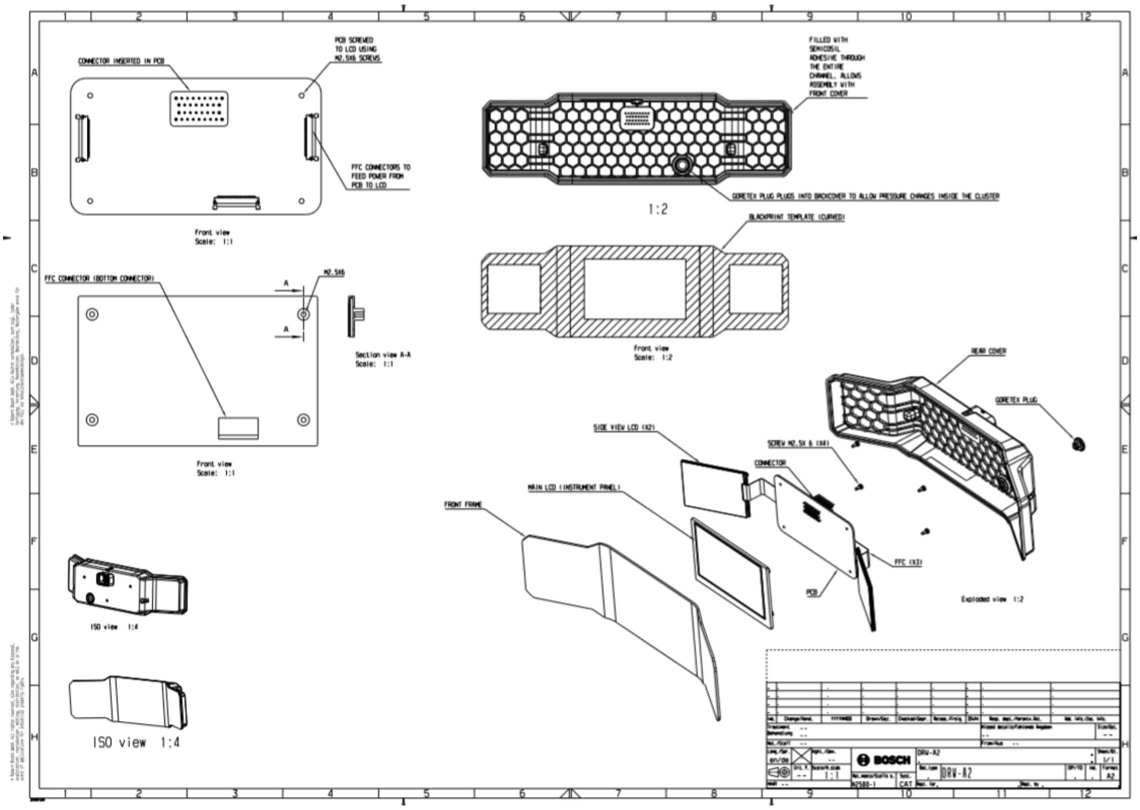


Figure 86 - Assembly technical draw

3.13 Cost

The cost of the instrument panel assembly is calculated by comparison to other similar products and components used at Bosch. In Table 15, it is possible to see the cost calculation of the assembly. However, it is important to remember, that depending with the production numbers of the component, the prices will fluctuate.

Table 15 - Cost calculation

Component/Process	Cost (€)
Rear cover	2.5
Front Frame	8
Main LCD	21
Side LCD (2x)	36
PCB with connectors	28
Screw (4x)	2
Gore plug	1.5
Assembly	15
Total	114

The approximate budget for this project would be around 114€ per instrument panel.

3.14 Render

In order to help to visualize the product in its application, a render is presented. A generic motorcycle CAD-model with the mirrors removed and the instrument panel positioned is utilized (Figure 87). The instrument panel has three separate LCD's. The vehicle information is presented in the main LCD, while the external LCD's will transmit live video about the incoming traffic, thus, replacing the mirrors. The instrument panel can be assembled to the PTW by different ways depending on the application. Mounting features can be added to the rear cover in order to allow the installation of the instrument panel to the motorcycle frame.

Figure 87 - Instrument panel render

In the Figure 88, it is possible to visualize how the instrument panel is mounted in a standard motorcycle cluster support.

Figure 88 - Instrument panel render (side view)

3.15 3D printing

In order to get a prototype of the instrument panel, 3D printing was utilized. Two iterations of the rear cover and one from the front frame were both 3D printed and assembled together. This way is easier to visualize how the component would look and function in a real world application. The printer utilized was the “Ultimaker S5” and the material chosen was Black pigment polylactic acid (PLA), which is a thermoplastic commonly used for this application. The scale model is present in Figure 89, Figure 90, Figure 91 and Figure 92.

Figure 89 - 3D printed rear cover scale model (front view)

Figure 90 – Close-up of the rear cover scale model

Figure 91 - 3D printed rear cover scale model (rear view)

Figure 92 - 3D printed front frame scale model (front view)

CONCLUSIONS

4 CONCLUSIONS AND PROPOSALS OF FUTURE WORKS

The purpose of this thesis was to study the viability of applying a new technology found in the automotive industry in to the PTW industry. This technology would replace the side mirrors by smaller and more aerodynamic cameras that would improve the efficiency of the vehicle, since both drag and surface area would be reduced. At the same time, this technology can achieve higher quality visual information for the user which could be beneficial, especially in more extreme light situations, as it happens during night time were light can be almost absent, or in during the higher luminosity hours of the day in which the sun may cause high brightness situations that may be hard to endure.

As such, a concept of an instrument panel was idealized. By removing the mirrors and installing two cameras on the rear sides of the PTW it was possible to increase the field of vision, while maintaining the visual information closer to the centre of the road, this way the user can get easier and safer access to the image of its surroundings. Other advantage found in using cameras over mirrors, was that cameras can adapt to the light that they are exposed, which means that they can tone down the sun glare or brighten up the dark of the night.

An instrument panel that could fit in most motorcycles was developed, design to assembly and design to manufacture ideologies were both used. By using industry proven materials and processes, that would grant the best result both in quality and economics, a final concept was developed.

After the development of the instrument panel, a rapid prototyping tool, 3D printing, was used. The scale model was revised, and an assembly was made in order to visualize the final product in a real life application.

For future work, new designs, applied to different segments of motorcycle, should be studied, thus, providing this technology to different PTW applications. As this is a new technology, camera placement should also be studied, in order to achieve the best viewing angle and clear image, as this is component that directly influences user safety.

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5 REFERENCES AND OTHER SOURCES OF INFORMATION

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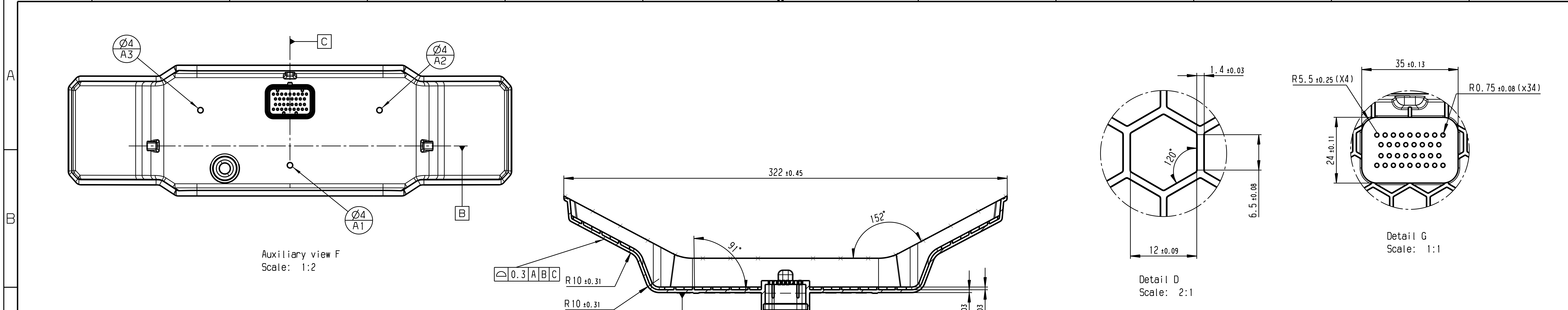
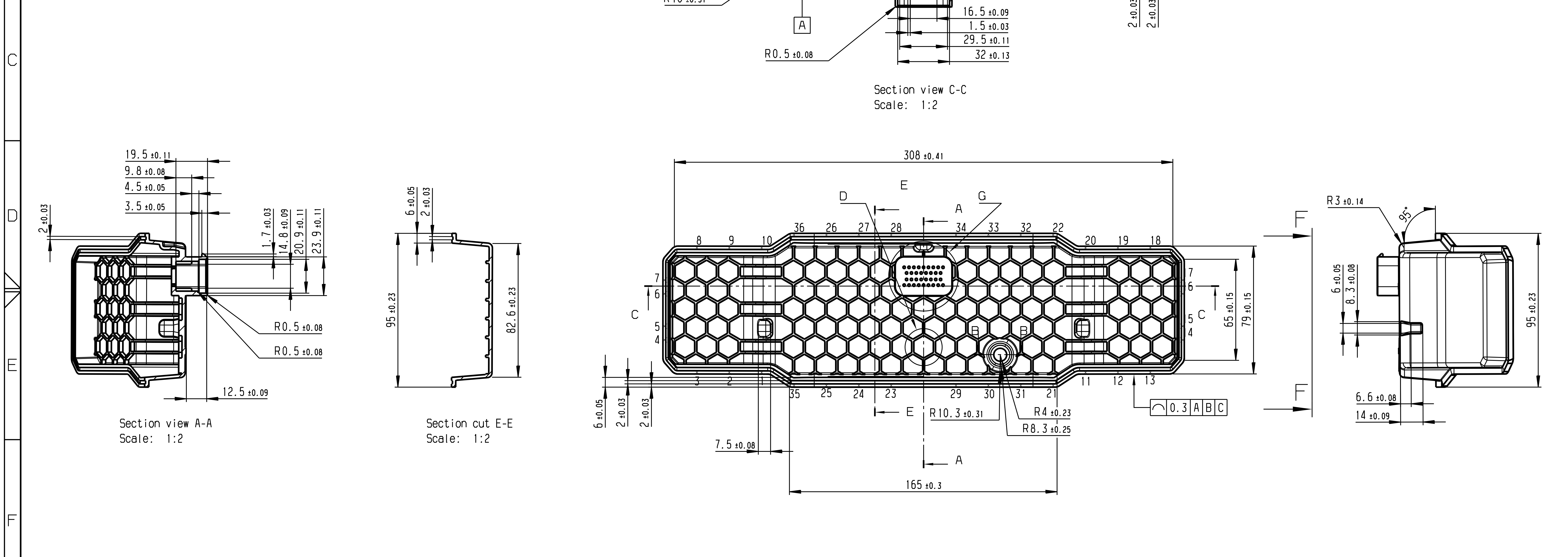
ANNEXES

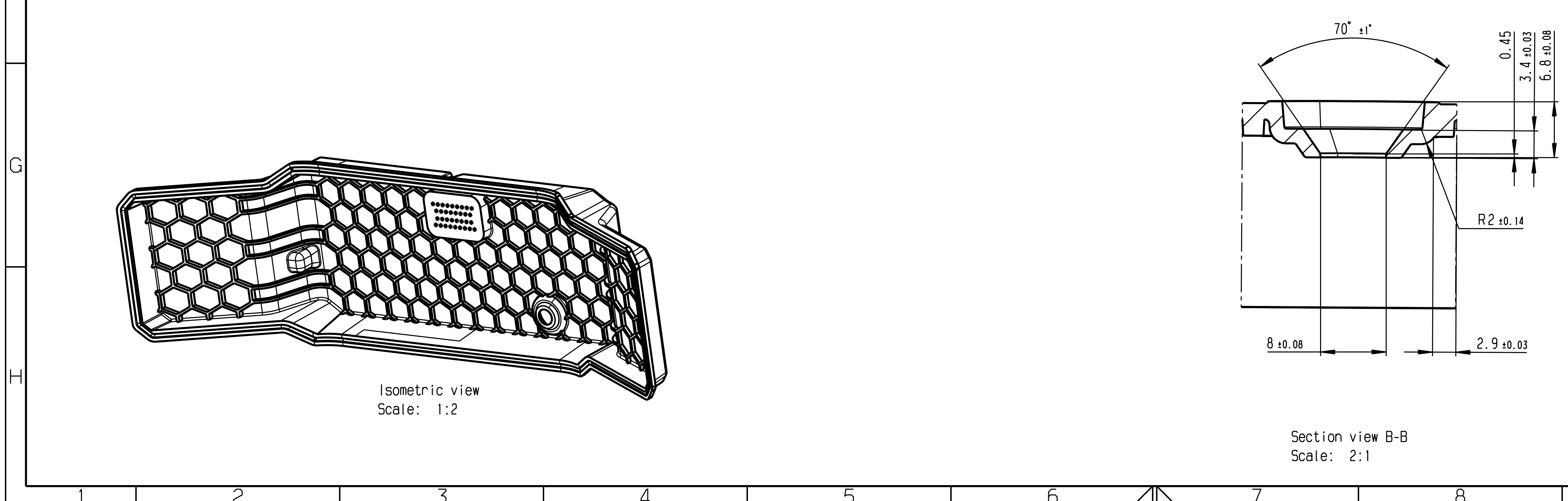
6 ANNEXES





Theoretical dimensions not underlined

REF.	A	B	C	tolerance
1	-38,45	-100	-53.39	±0.13
2	-49,04	-120	-53.39	±0.13
3	-59,62	-140	-53.39	±0.15
4	-70,2	-159,97	-33.39	±0.15
5	-70,2	-159,97	-24.89	±0.15
6	-70,2	-159,97	-4.89	±0.15
7	-70,2	-159,97	3.6	±0.15
8	-59,62	-140	23.6	±0.15
9	-49,04	-120	23.6	±0.13
10	-38,45	-100	23.6	±0.13
11	-38,45	100	-53.39	±0.13
12	-49,04	120	-53.39	±0.13
13	-59,62	140	-53.39	±0.15
14	-70,2	159,97	-33.39	±0.15
15	-70,2	159,97	-24.89	±0.15
16	-70,2	159,97	-4.89	±0.15
17	-70,2	159,97	3.6	±0.15
18	-59,62	140	23.6	±0.15
19	-49,04	120	23.6	±0.15
20	-38,45	100	23.6	±0.13
21	-28	80	-61.39	±0.11
22	-28	80	31.6	±0.11
23	-25,49	-20	-61.39	±0.11
24	-25,49	-40	-61.39	±0.11
25	-25,49	-60	-61.39	±0.11
26	-25,49	-60	31.6	±0.11
27	-25,49	-40	31.73	±0.11
28	-25,49	-20	31.6	±0.11
29	-25,49	20	-61.39	±0.11
30	-25,49	40	-61.39	±0.11
31	-25,49	60	-61.39	±0.11
32	-25,49	60	31.6	±0.11
33	-25,49	40	31.73	±0.11
34	-25,49	20	31.6	±0.11
35	-28	-80	-61.39	±0.11
36	-28	-80	31.6	±0.11



Ind.	Change/Aend.	YYYYMMDD	Drawn/Gez.	Checked/Gepr.	Releas./Freig.	BWN	Resp. dept./Verantw.Abt.	Add. info./Zus. Info.
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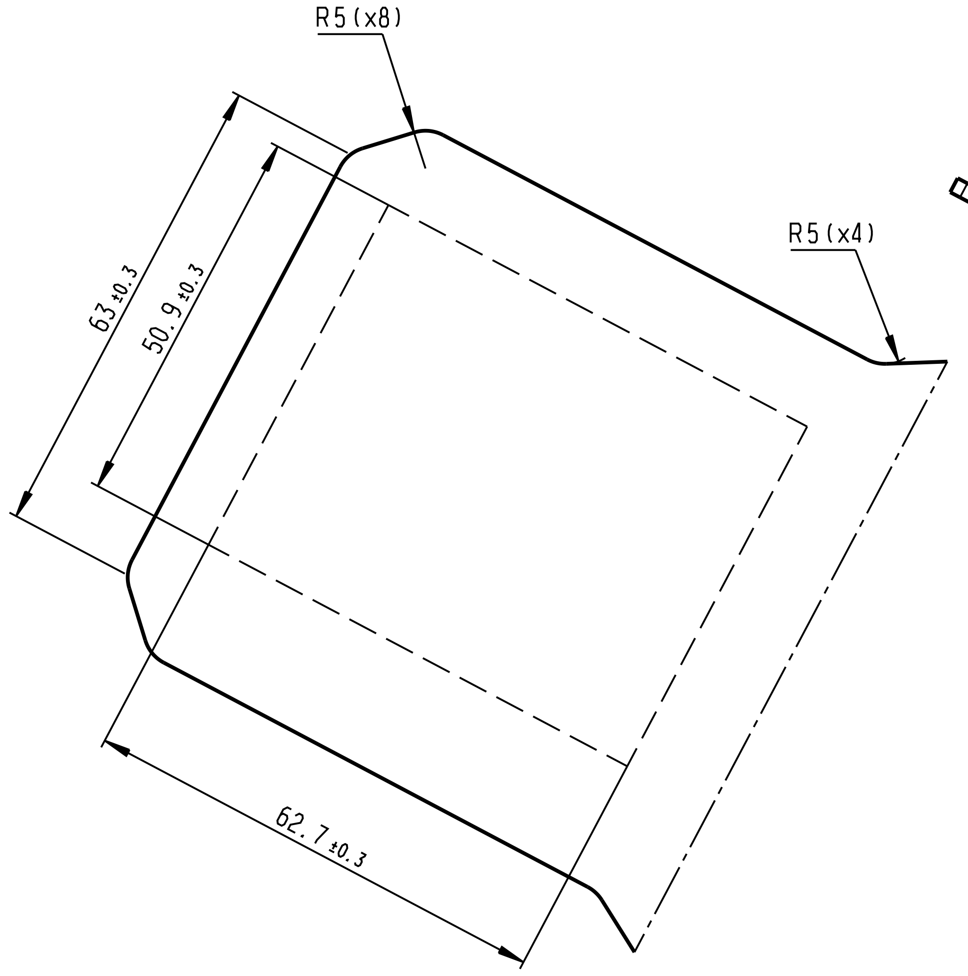
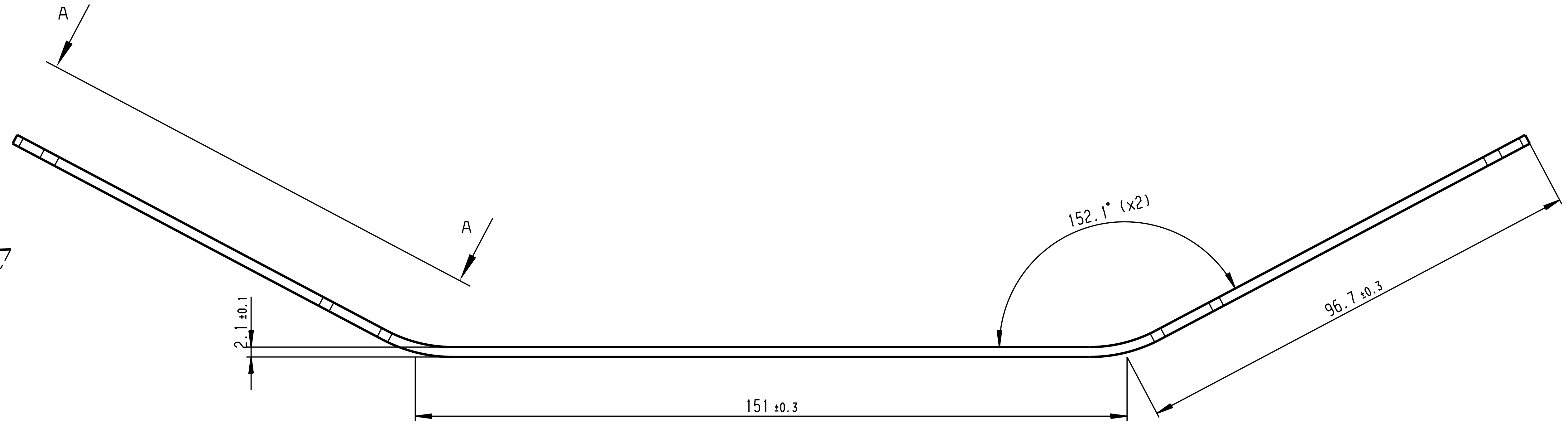
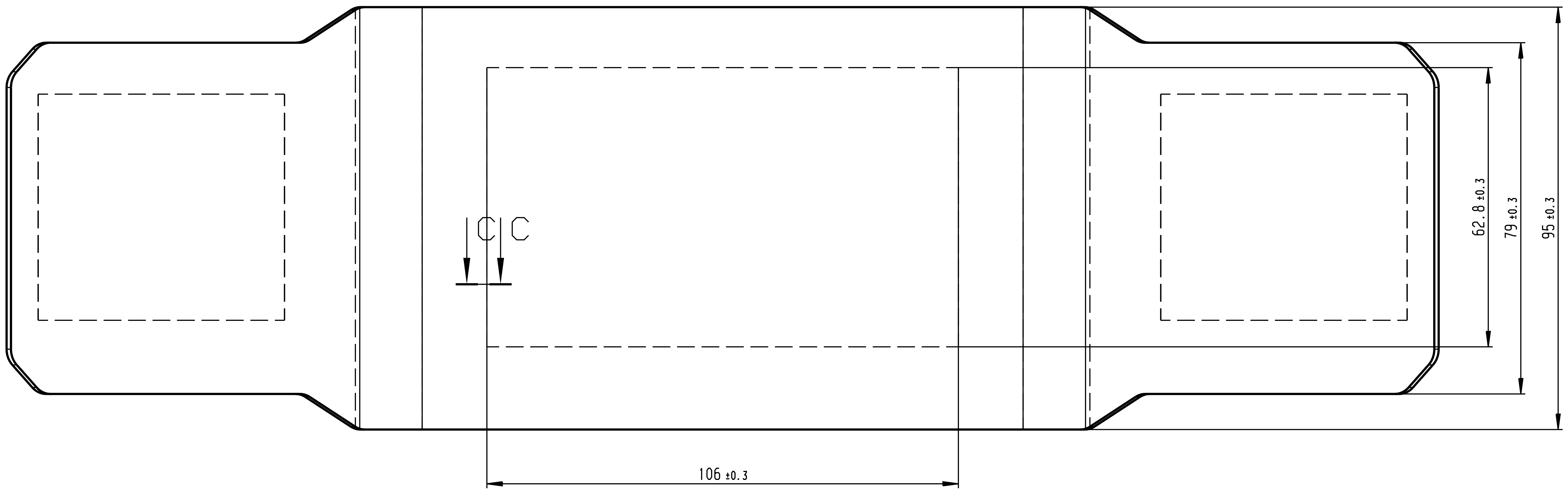
01	New	20190306	CSR2BRG	.	.	815	CM-CI2/ECM7	.

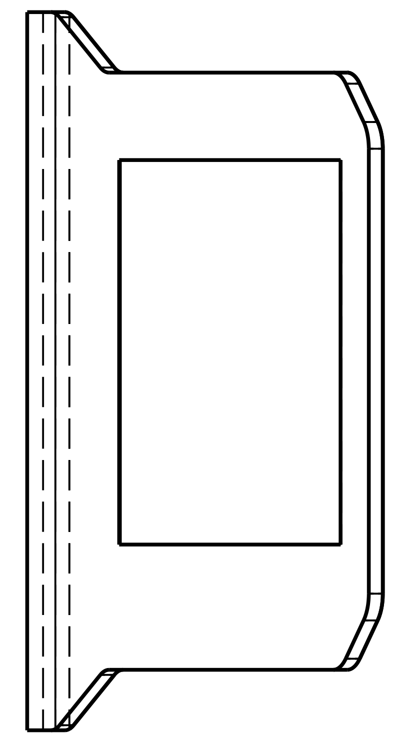
Treatment / Behandlung -- --
Missed details/Fehlende Angaben --
Size/Gst. --
Mat./Stoff --
From/Aus --
Lang./Spr. en/de
Wght./Gew. --
BOSCH
DRW-A2
Sheet/Bl. 1/1
Crit. P. --
Scale/M.stab 1 : 1
Mat.meets/Stoffe s. N2580-1
Syst. CAT
Doc.type DRW
DRW-A2
DP/TD .
Ind. 01
Format A2
MNR --
Repl. for .
Repl. by .

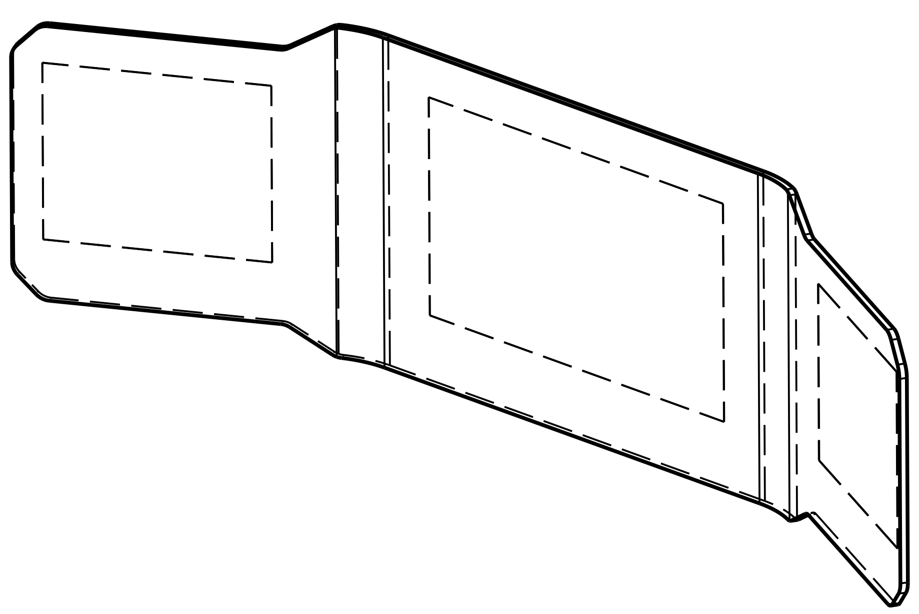


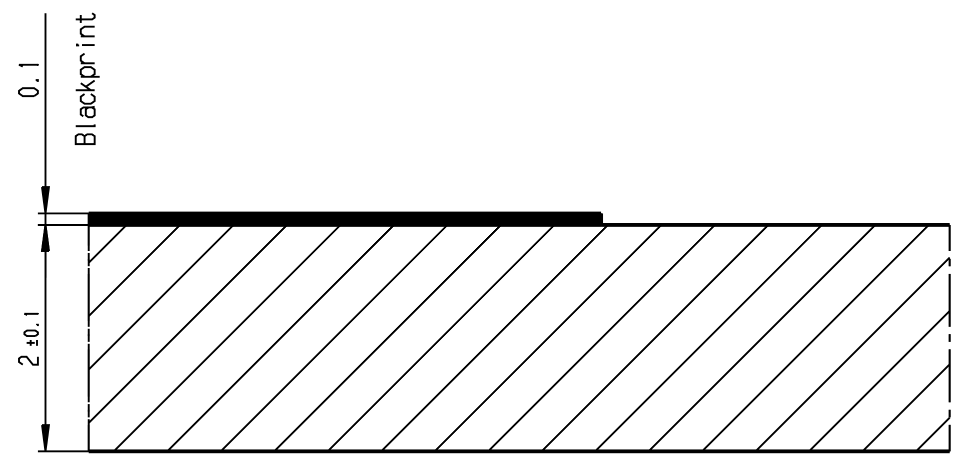
Auxiliary view A
Scale: 1:1











Section cut C-C
Scale: 15:1

Ind.	Change/Aend.	YYYYMMDD	Drawn/Gez.	Checked/Gepr.	Releas./Freig.	BWN	Resp. dept./Verantw.Abt.	Add. info./Zus. Info.
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02	New	20190306	CSR2BRG	.	.	815	CM-CI2/ECM7	.

Treatment -- Behandlung --

Missed details/Fehlende Angaben --

Size/Gst. --

Mat./Stoff --

From/Aus --

Lang./Spr. en/de

Wght./Gew. --

BOSCH

DRW-A2
.

Sheet/Bl. 1/1

Crit. P. --

Scale/M.stab 1:1

Mat.meets/Stoffe s. N2580-1

Syst. CAT

Doc.type .

DRW-A2

DP/TD .

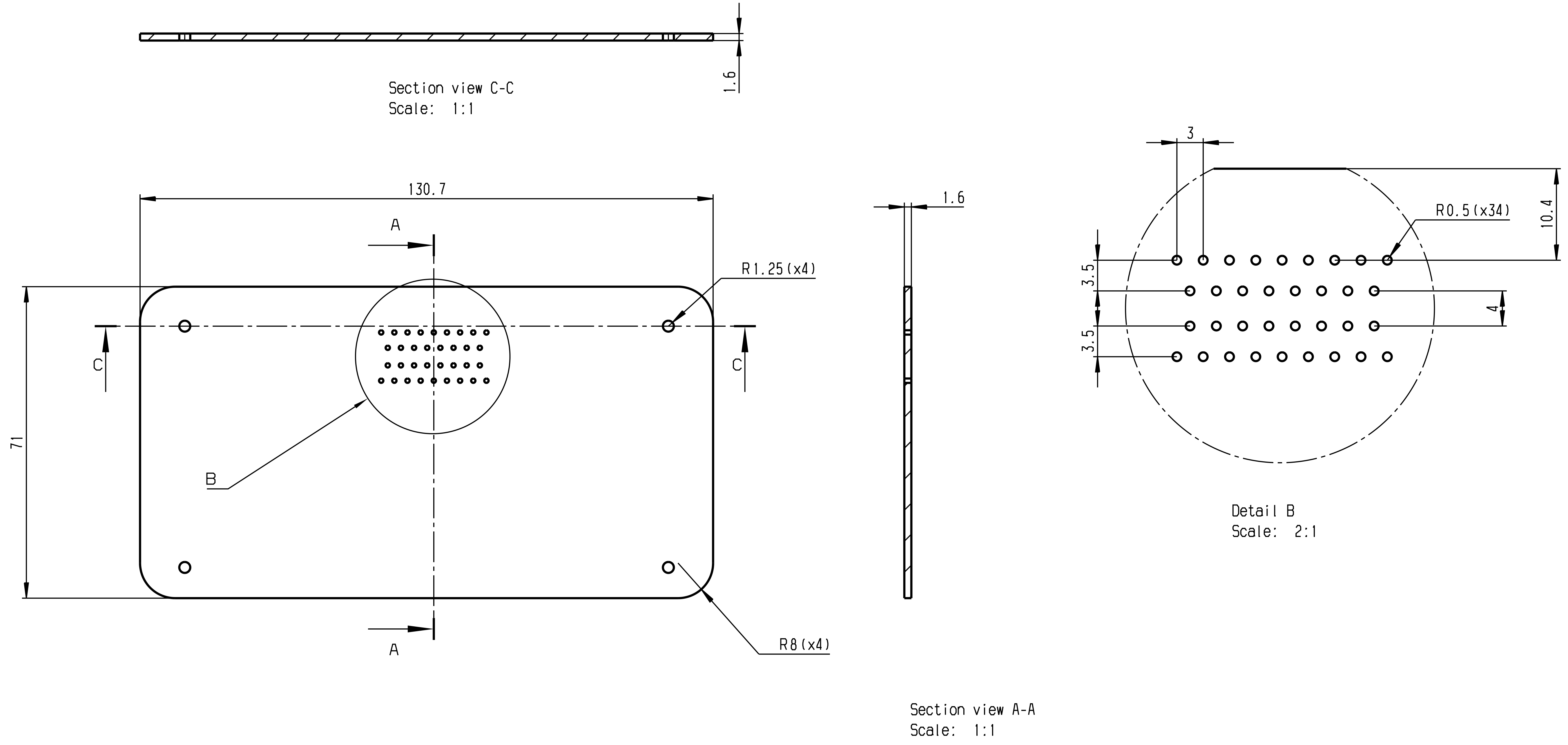
Ind. 02

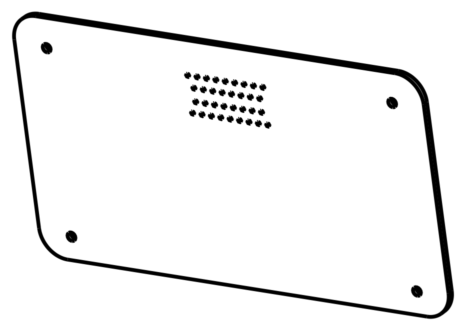
Format A2

MNR --

Repl. for .

Repl. by .





Isometric view
Scale: 1:2

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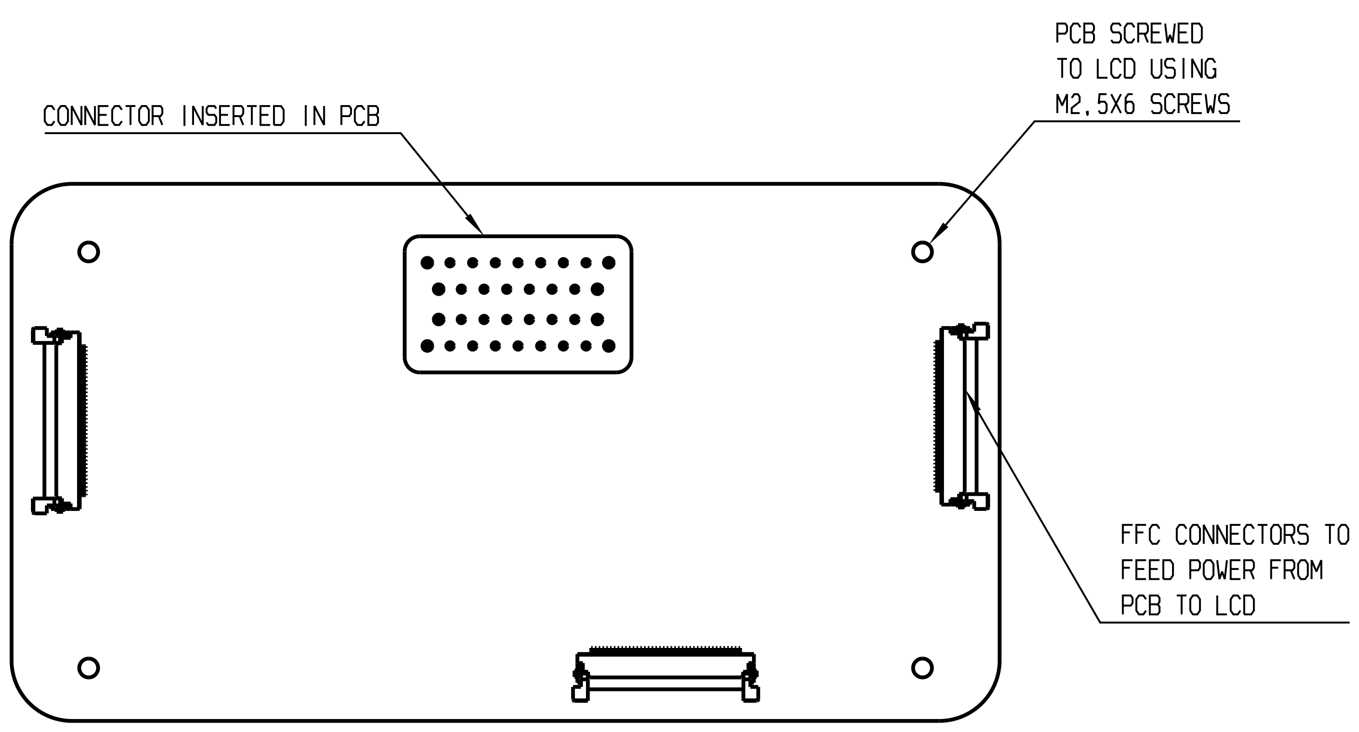
03	New	20190306	CSR2BRG	.	.	815	CM-CI2/ECM7	.
Ind.	Change/Aend.	YYYYMMDD	Drawn/Gez.	Checked/Gepr.	Releas./Freig.	BWN	Resp. dept./Verantw.Abt.	Add. info./Zus. Info.

Treatment / Behandlung: -- --
Missed details/Fehlende Angaben: --
Size/Gst.: --
Mat./Stoff: --
From/Aus: --
Lang./Spr.: en/de
Wght./Gew.: --
Crit. P.: --
Scale/M.stab: 1:1
Mat.meets/Stoffe s.: N2580-1
Syst.: CAT
MNR: --

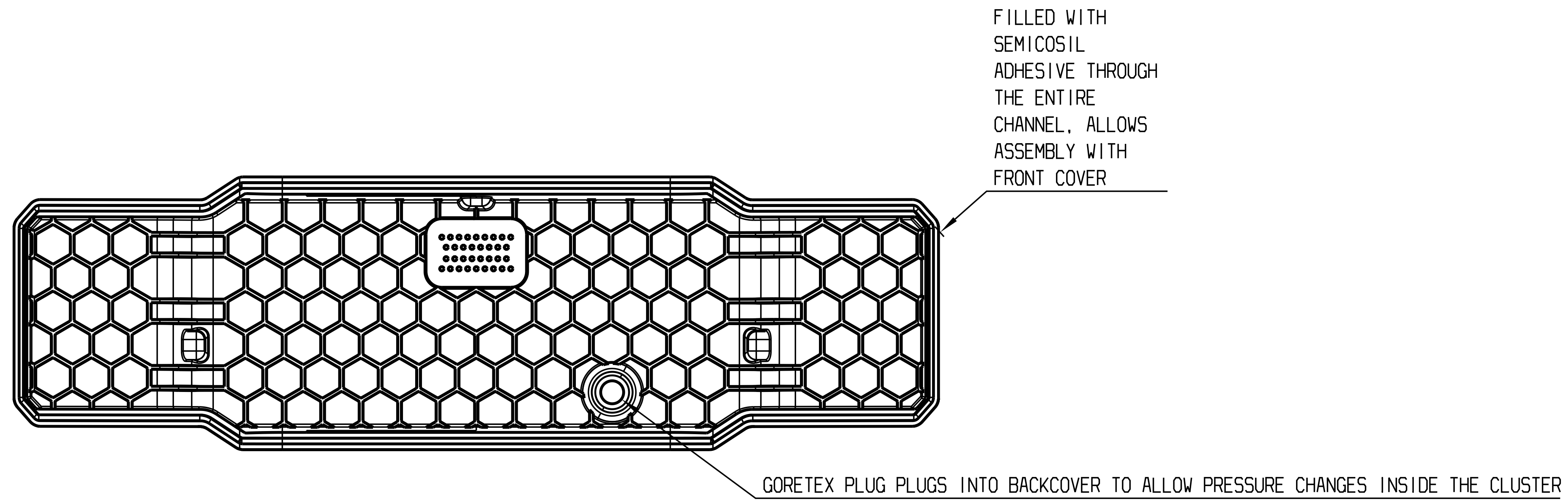
BOSCH

DRW-A3
Sheet/Bl.: 1/1
Doc.type: . DRW-A3
DP/TD: .
Ind.: 03
Format: A3
Repl. for .
Repl. by .

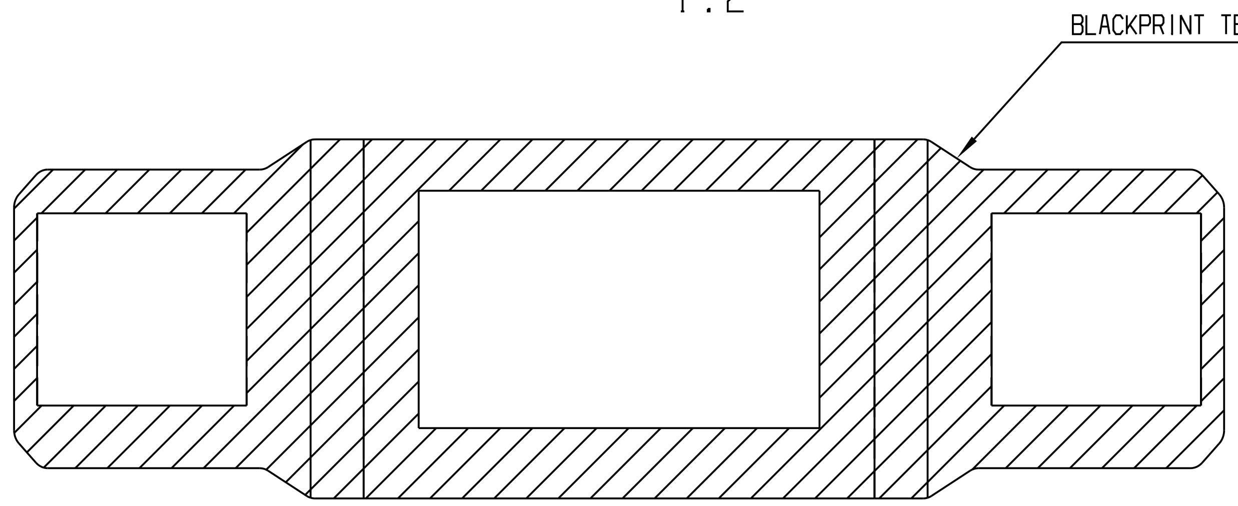
B043/V001



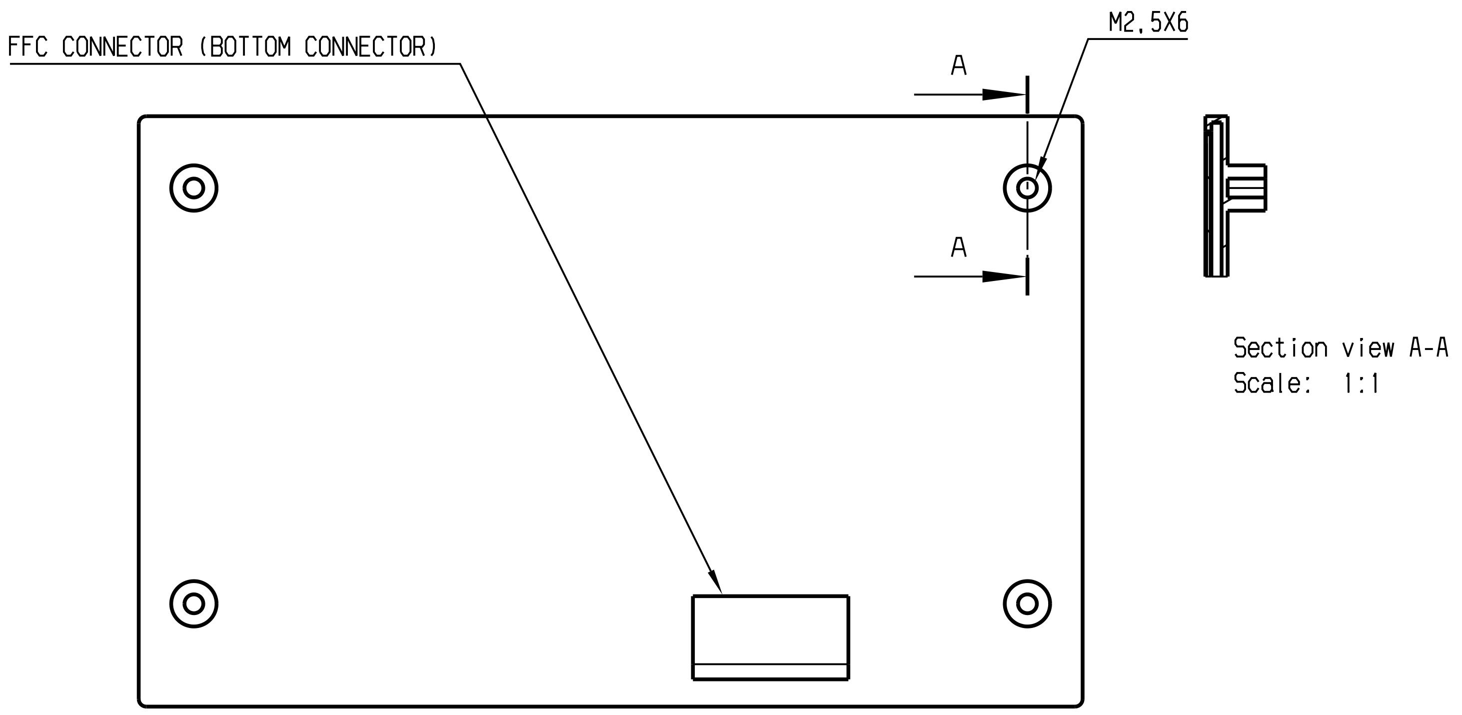
Front view
Scale: 1:1



1:2

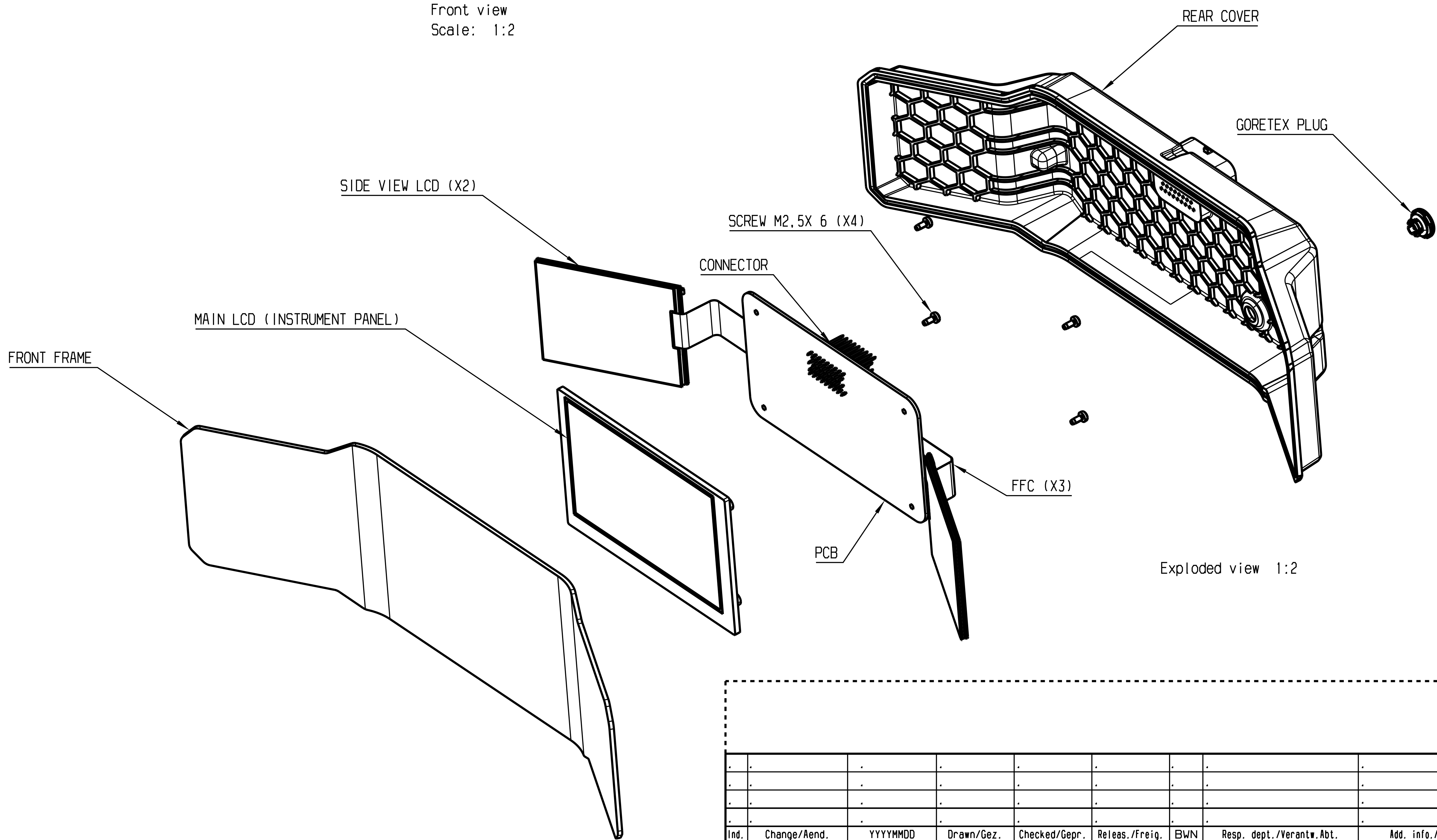


Front view
Scale: 1:2

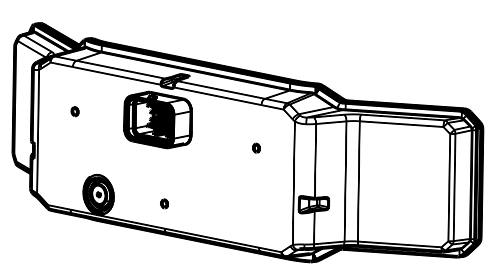


Front view
Scale: 1:1

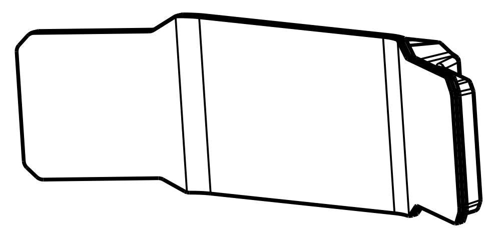
Section view A-A
Scale: 1:1



Exploded view 1:2



ISO view 1:4



ISO view 1:4

Ind.	Change/Aend.	YYYYMMDD	Drawn/Gez.	Checked/Gepr.	Releas./Freig.	BWN	Resp. dept./Verantw.Abt.	Add. info./Zus. Info.

Treatment Behandlung -- --		Missed details/Fehlende Angaben --	Size/Gst. --
Mat./Stoff --		From/Aus --	
Lang./Spr. en/de	Wght./Gew. --	DRW-A2	Sheet/Bl. 1/1
Crit. P. --	Scale/M.stab 1:1	Doc.type DRW-A2	DP/TD . Ind. . Format A2
MNR --	Mat.meets/Stoffe s. N2580-1	Syst. CAT	Repl. for . Repl. by .

BOSCH

Ficha técnica PLA

Ultimaker

Nome químico	Poliácido láctico
Descrição	O filamento de PLA da Ultimaker proporciona uma experiência de impressão 3D sem complicações graças à sua fiabilidade e acabamento superficial de boa qualidade. O nosso PLA é fabricado a partir de fontes orgânicas e renováveis. É seguro, de fácil impressão e satisfaz uma ampla gama de aplicações para utilizadores tanto principiantes como avançados.
Características principais	Boa resistência à tração e qualidade da superfície, de trabalho fácil a elevadas velocidades de impressão, de fácil utilização em ambiente tanto doméstico, como de escritório; o PLA permite criar peças de elevada resolução. Existe uma ampla gama de opções de cores disponíveis.
Aplicações	Utensílios domésticos, brinquedos, projetos educativos, objetos de exposição, protótipos, modelos arquitetónicos, assim como métodos de moldagem por envolvimento para criar peças de metal.
Não adequado para	Aplicações em contacto com alimentos e aplicações in vivo. Uso ou aplicações de longa duração em espaços exteriores onde a peça impressa está exposta a temperaturas superiores a 50 °C.

Especificações do filamento	Valor	Método
Diâmetro	2,85±0,10 mm	-
Desvio máx. de circularidade	0,10 mm	-
Peso líquido do filamento	350 g / 750 g	-
Comprimento do filamento	~44 m / ~95 m	-

Informação sobre cores	Cor	Código da cor
	PLA verde	RAL 6018
	PLA preto	RAL 9005
	PLA cinza metalizado	RAL 9006
	PLA branco	RAL 9010
	PLA transparente	n/a
	PLA cor de laranja	RAL 2008
	PLA azul	RAL 5002
	PLA magenta	RAL 4010
	PLA vermelho	RAL 3020
	PLA amarelo	RAL 1003
	PLA branco pérola	RAL 1013

Propriedades mecânicas (*)

Propriedades mecânicas (*)	Moldagem por injeção		Impressão 3D	
	Valor típico	**Método do teste**	**Valor típico**	**Método do teste**
Módulo de tração	-	-	2346,5 MPa	ISO 527 (1 mm/min.)
Resistência à tração no limite	-	-	49,5 MPa	ISO 527 (50 mm/min.)
Resistência à tração na rutura	-	-	45,6 MPa	ISO 527 (50 mm/min.)
Alongamento no limite	-	-	3,3%	ISO 527 (50 mm/min.)
Alongamento na rutura	-	-	5,2%	ISO 527 (50 mm/min.)
Resistência à flexão	-	-	103,0 MPa	ISO 178
Módulo de flexão	-	-	3150,0 MPa	ISO 178
Resistência ao impacto Izod, com entalhe (a 23 °C)	-	-	5,1 kJ/m^2	ISO 180
Resistência ao impacto Charpy (a 23 °C)	-	-	-	-
Dureza	-	-	83 (Shore D)	Durómetro

Propriedades térmicas

Propriedades térmicas	Valor típico	Método do teste
Taxa de fluxo de massa fundida (MFR)	6,09 g/10 min.	ISO 1133 (210 °C, 2,16 kg)
Deflexão térmica (HDT) a 0,455 MPa	-	-
Deflexão térmica (HDT) a 1,82 MPa	-	-
Transição vítrea	~60 °C	ISO 11357
Coeficiente de expansão térmica	-	-
Temperatura de fusão	145 – 160 °C	ISO 11357
Retração térmica	-	-

Outras propriedades

Outras propriedades	Valor típico	Método do teste
Gravidade específica	1,24	ASTM D1505
Classificação da chama	-	-

(*) Ver notas.

Notas

As propriedades reportadas no presente documento correspondem à média de um lote típico. As amostras de testes de impressão 3D foram impressas no plano XY, utilizando o perfil de qualidade normal no Cura 2.1, uma Ultimaker 2+, um bocal de 0,4 mm, 90% de enchimento, temperatura do bocal de 210 °C e da placa de impressão de 60 °C. Os valores representam a média de 5 amostras brancas e 5 amostras pretas para os testes de tração, flexão e impacto. A dureza de Shore D foi medida num quadrado com uma espessura de 7 mm impresso no plano XY, utilizando o perfil de qualidade normal no Cura 2.5, uma Ultimaker 3, um núcleo de impressão de 0,4 mm e 100% de enchimento. A Ultimaker está constantemente a trabalhar na expansão dos dados da ficha técnica.

Isenção de responsabilidade

Qualquer assistência ou informação técnica constante no presente documento é fornecida e aceite à responsabilidade do utilizador; a Ultimaker e as suas afiliadas não dão qualquer garantia relacionada ou derivada da mesma. A Ultimaker e as suas afiliadas não serão responsáveis pela utilização destas informações nem de nenhum produto, método ou aparelho mencionado, tendo o utilizador de fazer a sua própria determinação da adequação e exequibilidade para a sua própria utilização, para a proteção do ambiente e para a saúde e a segurança dos seus funcionários e dos compradores dos seus produtos. Não é dada nenhuma garantia de comerciabilidade ou adequação de nenhum produto; nada no presente documento revoga nenhuma das condições de venda da Ultimaker. As especificações estão sujeitas a alterações sem aviso prévio.

Versão	Versão 3.011
Data	16/05/2017

Ultimaker