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Research paper

Development of the HASHWallet charger

Research paper about the development of an optimal charging device for small-scale lithium ion batteries, that are used in the HASHWallet.

Author:
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eSignus

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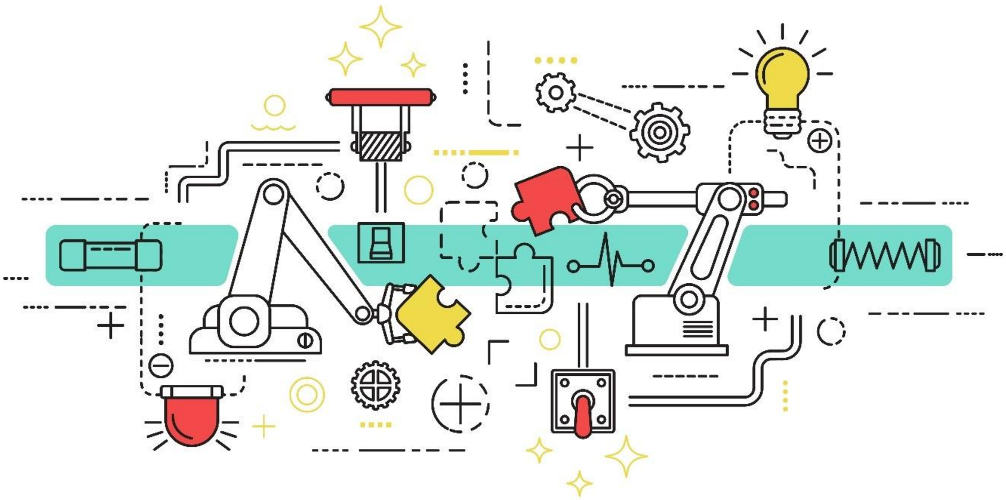

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Preface:

This research paper is about the complete process of the development of the HASHWallet charger, this includes prescheduling, researching, designing, prototyping and it includes the manufacturing setup. The paper is written as a hardware related project for eSignus.

The research paper is written for all the hardware engineers, specialists, and managers within the eSignus group. Therefor the research paper consists of nine chapters based on the DMADOV methodology. For specialists and decision makers who are interested in the research work that has been compiled within this report, should read the summery and conclusion/recommendations in chapter nine. For engineers, specialists or decision makers that would like to know more about additive manufacturing, design for manufacturing or injection moulding techniques I recommend reading the in-depth chapters and accompanying attachments.

First, I would like to thank Sebastián Unda (UX Design lead), José Ramón Sendra (Co-Founder & CTO) and Daniel Hernández Rogríguez (Co-Founder & CEO) from eSignus for their valuable input and support during the whole development of the HASHWallet charger. In addition, I would like to thank Karin van der Steen, Teacher from Avans University of Applied Sciences for providing advice and valuable feedback on the research paper. Finally, I would like to thank the company eSignus and all their employees for accommodating me and helping with the development of the project.

Las Palmas de Gran Canaria, January 2022
Dylan Dreyer Varsics

Summary:

This research paper is about the development of the HASHWallet chargers. This includes the scheduling, researching, designing, prototyping and the manufacturing setup. The objective is developing a charger that can charge the current (founders) and future editions of the HASHWallet´s. This charger should be portable, have a USB-C connector and be designed with durability in mind. The designs needed to be finished before 12 January 2022. With this research paper the fallowing main question was answered “What is the most effective method to develop the first version of the charger for a production of maximum of 300 units and what is the most effective method to mass produce the final version of the HASHWallet charger?’’

The DMADOV methodology was chosen in combination with the agile sprints as main project method to ensure that the project could be carried out like planned. Every two weeks there was a general meeting to close and open new sprints. Within the sprints new project goals were carried out or added to the already pre-determined goals. The collected data within this paper is mainly based on the survey and the research that was conducted around design for manufacturing. The customer requirements were based on the survey and conducted research on the targeted audience. The survey was sent out to different end users, within the targeted audience. A lot of data around design for manufacturing was collected in the measure phase to ensure that the final designs could be manufactured. Besides that, the collected data was used to determine the most effective manufacturing methods of the chargers.

The results from the research have shown that the first version of the HASHWallet charger should be manufactured by utilizing the selective laser sintering (SLA-printing) method. For the first version of the charger only 300 units should be produced. For the mass production version, the utilization of injection moulding would be the most effective solution. Because this ensures a relative low cost, but high-quality product, when done correctly. The recommendations are to invest more time and resources in redesigning the mass production version of the charger to ensure a high-quality final product. Besides that, it would be beneficial cooperate with a manufacturer and mould design company, to ensure that the manufacturing process is flawless. Building one or multiple moulds can get expensive, and it is advised to only invest in an injection mould when the output of chargers are listed as mid or high-volume manufacturing. This means that the output of charger needs to become greater than 5000> units. For low-volume production (<500 units) it is recommended to use additive manufacturing techniques in combination with the first designed charger.

Table of Contents

Chapter 1: Introduction

The first chapter is an introduction to the full research and development of the HASHWallet charger. The main reason for the project assignment, containing important background information is described and elaborated on in the first paragraph (1.1). The main purpose of the project assignment, containing the project goals, main question, research methods and conditions are noted in the second paragraph (1.2). The research structure is compiled in paragraph (1.3). The final paragraph will be an overall conclusion of this chapter.

1.1 Reason for the project assignment

eSignus is focussing on the development of multiple hardware wallets. The first hardware wallet that the company is developing is called the HASHWallet. This hardware wallet comes with many advanced hardware components like an, e-ink display, fingerprint scanner, printed circuit board, controller unit, snap sensor, and a thin lithium-ion battery. These components are packed within a relatively small space. The dimensions of the HASHWallet (85.6x53.03x2mm) is not much larger than a regular credit card (85.6x53.9x1.58mm). Therefor it is difficult to design such a device with that many features. One of the features that the HASHWallet has that strands out from the competitors is that the HASHWallet could be charged wirelessly. But this extra feature caused some problems, because wireless pads and mobile phones that support reverse wireless charging differ a lot with charging power and beam pression. With this limitation the battery could not always charge and offer enough power while operating the device at the same time. Besides that, not all end users have wireless chargers at home or phones that offer reverse wireless charging. Therefor a new dedicated charger needed to be developed.

1.2 purpose of the project assignment

The project objective is to design a charger that can charge the HASHWallet. The charger must be portable, have a USB-C connector and be designed with durability in mind. It is important that the charger does not damage the HASHWallet, by offering minimal friction but still having enough grip to hold the hardware wallet in place. Besides that, the HASHWallet needs to be fully operational while being charged. Therefor the charger must not obstruct the screen, indication LED lights and fingerprint scanner. The final deadline of the research paper is on 12th January, but the first operational prototypes of the chargers need to be finished before the planned events. This deadline is placed on the 27th of November. The first protype charger should be similar to the second version that will be delivered with the founder edition HASHWallet. This version of the HASHWallet will be delivered to the backers that have backed (funded) the IndieGoGo campaign (Indiegogo, 2020). There need to be 300 chargers produced before Q2 2022 to supply all backers with their dedicated charger. This charger will be included within the packaging for the HASHWallet. The third and final version of the charger should be optimised for mass production (5000+) units. This charger should be similar in design but design for manufacturing should be the main guideline while designing these chargers for the HASHWallet.

Project objective

The project objective is developing a charger that can charge the current (founders) and future editions of the HASHWallet´s. The charger should be portable, have a USB-C connector and be designed with durability in mind. The charger designs need to be finished before Q1 2022.

Main Question:

What is the most effective method to develop the first version of the charger for a production of maximum of 300 units and what is the most effective method to mass produce the final version of the HASHWallet charger?

Project method:

For this project the DMADOV methodology will be used to guarantee that the project is well defined, measured, analysed, designed, optimised, and verified. See figure 1.1 for a visualised view of the project setup. This six-sigma project methodology is well suited for the project because of the project complexity. This methodology will be combined with agile sprints to ensure that the team members operate in sprint phases. These sprints are set at every two weeks and deadlines are planned within a

Kanban board. eSignus uses an online tool called Notion to plan and share all the progress that has been made. At the end of every sprint there will be a general meeting where the team members discuss the progress of the project. Please read more about the project method in attachment 1, chapter 1 (Define phase).

Project setup:
1. **Define** (defining the project goals and project setup)
2. **Measure** (Measuring and determining requirements**)**
3. **Analyse** (analysing available information and doing research into manufacturing techniques)
4. **Design** (Design first batch version with prototypes)
5. **Optimise** (Design mass production version with prototypes)
6. **Verify** (verify the final designs and determine efficient production methods)

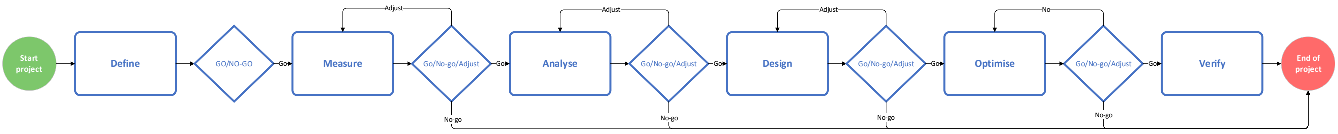


Figure 1.1 DMADOV project methodology

Scope of the project and project requirements:
The scope of the project is the complete the define, measure, analyse, design, optimise, and verify process of the two versions of the charger. The chargers will be realized by using multiple 2D/3D tools. Like fusion 360 and 3ds max. DMADOV will be the leading project methodology in combination with the agile sprints. In table 3.2 all the in and out of scope deliverables are noted. These have been verified at the start of the project. Please read more about the project scope in attachment 1, chapter 1 (Define phase).

Table 1.2 In and out of the project scope

In scope	Out of scope
Full DMADOV research documentation	Designing different charging methods
3D and 2D Designs of the first and optimised version of the charger	designing a charger for a different hardware wallet
Prototypes of the chargers	Making more than the two final versions of the HASHWallet
Final version of the charger (founder edition HASHWallet charger – 300 units)	
Final charger for future HASHWallet production (mass production)	
Manufacturing research	
Customer research	

1.3 Structured description of the report
The main chapters will be fallowing the DMADOV methodology and answering the main and sub-questions. The separate DMADOV methodology phases existing of design, measure, define, optimise, and verify fazes will be separately elaborated on within the references.

Conclusion:
The dedicated charger of the HASHWallet needs to be developed because of ongoing technical difficulties with the Lithium-ion battery and wireless charging method within the HASHWallet. Therefor the project objective, main question has been noted and the project setup including goals have been defined within the first chapter. The project objective is, developing a charger that can charge the current (founders) and future editions of the HASHWallet´s. The charger should be portable, have a USB-C connector and be designed with durability in mind. The charger designs need to be finished before Q1 2022. The project will fallow the DMADOV methodology in combination with agile sprints to ensure that the project is well planned and structured.

Chapter 2: Theoretical framework, sub-questions & research method

The second chapter is an in-depth chapter about the theoretical framework of the project. In the first paragraph the acquired and existing knowledge is presented in a structured way (2.1). With this information a conceptual model is visually presented in the second paragraph (2.2). The sub-questions will be based on the conceptual model and be noted in the third paragraph (2.3). The final paragraph will be an overall conclusion of this chapter.

2.1 Theoretical framework

Before starting this project, it is important to have a basic understanding of different charging methods, different battery types/specifications and to know what type of project tools to use to realize this project.

With the rapid growth of portable devices, the needs for finding efficient solutions to charge these products has increased. Therefor it is important to have a good understanding what type of method for charging lithium-ion batteries is the best to use for development of the charger.

> The demand for portable products is showing exponential growth with no end in immediate sight. Along with the overall growth in volume has come increased demand for greater features and functions. This combination has brought the issue of power management to the forefront of engineering design considerations. The overall success of a portable product will not only be dictated by its features and functions, it will also be influenced by how long it can perform before running out of power, the time it takes to return the batteries to full capacity and the life expectancy of the battery. Sound engineering design begins with a good working knowledge of batteries and battery charging techniques (Cope & Podrazhansky, 1999)

Project management methodology:
For this project the DMADOV methodology is used to guarantee that the project is well orientated, analysed, designed, and is realised. The structure of the project will be based on the fallowing literature of “projectmanagement op maat, Ariane Moussault” This book goes more in depth with project management tools.

The agile Kanban board from eSignus will further help with the development of the project. With this tool it is possible to setup the project in different sprints and easily share progress with different project members. This further increases the output of the development of the project.

Project structure:
The main project structure is based on “rapportage-techniek, from Rien Elling” This book describes how certain chapters and paragraph should be written within a research-based project.

Tools for the project:
To meet the required goals there will be used certain tools like 3D computer-aided-design software like fusion 360 and other 3D/2D software to visualize the final designs. Besides that, simulation software will help with the final validation of the mass production version of the charger. The documentation part will be created with Microsoft Word, excel and Visio. These tools should be well mastered before the final deadlines on 12th of January are met. It is upon most importance that the final deliveries are from industry standard quality.

Important theoretical knowledge:
Different rechargeable battery types:

1. Nickel cadmium batteries
2. Nickel metal hydride batteries
3. Lithium-Ion batteries
4. Sealed lead acid batteries

Rechargeable battery used in the HASHWallet:
eSignus uses thin Lithium-Ion batteries in their HASHWallet, because lithium-ion batteries can be very light, thin and can be recharged for many cycles (when used correctly).

> Lithium-ion batteries (LIBs) are considered the pioneering technology that has been successfully adopted as a power source for wide range of applications including portable electronics and electric/hybrid electric vehicles (EVs/HEVs) after their commercialization by Sony Corporation in 1991 (Perveen et al., 2020; Duan et al., 2020; Tian et al., 2020). Despite their commercial success in numerous applications, LIBs have not been deployed in large-scale electrical energy storage (EES) applications due to elevated cost and limited supply of lithium resources over the coming years. (H.Qiao, 2012)

Different charging methods for Lithium-Ion batteries:
Li-Ion battery chemistries utilize a constant, or controlled, current and constant voltage algorithm that can be broken-up into four stages: (1) trickle charge, (2) constant current charge, (3) constant voltage charge and (4) charge termination (Cleveland & Dearborn, z.d.)

1. Trickle Charge
2. Constant Current charge
3. Constant voltage charge
4. Change Termination

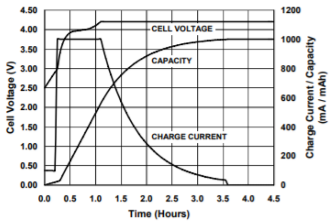


Figure 1: Li-Ion Charge Profile

Figure 2.2 Li-Ion Charge profile (Cleveland & Dearborn, z.d.)

2.2 Conceptual model

In the conceptual model (figure 2.3) "charging methods" stands central from the main question. And the other depended, independent and moderator variables are used to map the relationships of these variables to the central main question "charging methods".

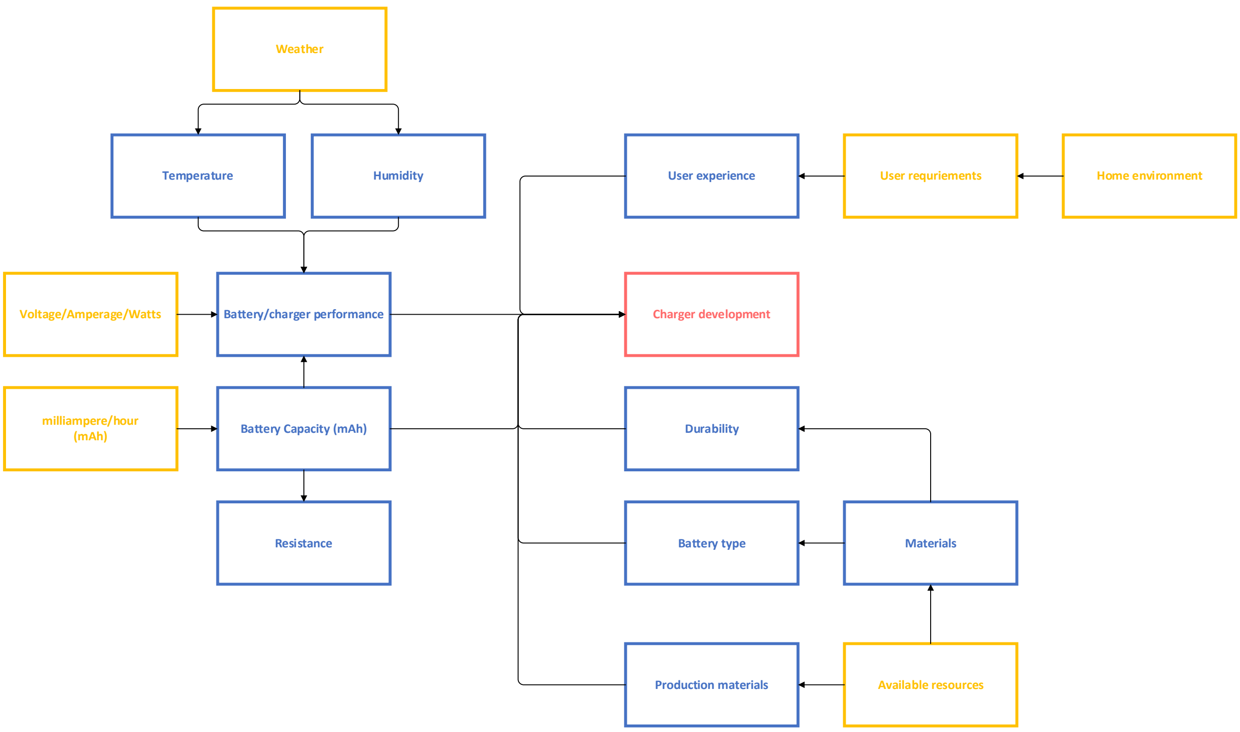


Figure 2.3 Conceptual model "charger development"

2.2 Sub-questions

The Sub-questions are compiled and are sorted in the DMADOV methodology phases. This makes the research paper clearer and easier to understand. Please read the listed sub-questions below. The sub questions are answered in all the chapters and conclusions.

Define:

- What is the project approach and how will the goals be defined?

Measure:

- What are the risks and how can they be measured?
- What is the schedule that must be met, and what are suitable milestones?
- What requirements do customers and end-users have?

Analyse:

- *What type of production method is best suited for small and large batches?*
- *Which types of materials will be best suited for the mass production of the charger?*
- *How will the charger be durable, repairable, and recyclable?*

Design:

- *Which charger design is best suited for a production size of 300 units?*
- *Will the final specifications and dimensions change before optimising the design?*

Optimise:

- *What type of adjustments must be made before the charger can be mass-produced?*
- *Does the final charger have all requirements set?*

Verify:

- *What type of production method(s) will be best suited to produce both versions of the charger?*

Conclusion:

Before starting this project, it is important to have a good understanding of different charging methods, battery types, and project management tools. As described in the first chapter the leading project methodology is based around the DMADOV setup. The information of this methodology is based on the fallowing literature of “projectmanagement op maat, Ariane Moussault” This book goes more in depth with different project management tools. The project structure is based on “rapportage-techniek, Rien Elling” and the other research information is compiled from multiple online sources, listed in the bibliography. With this information the conceptual model has been created where the sub-questions are based on. The sub-questions have later been compiled in the DMADOV methodology phases to make the research paper clearer and easier to understand.

Chapter 3: Research methods

The third chapter will describe the research methods that were used to collect and process the required data for the development of the charger. The first chapter will be about using surveys to collect the user requirements (3.1). The second chapter will be about different research tools that will be used within the project to determine different charger requirements (3.2). The final paragraph will be an overall conclusion of this chapter.

3.1 Using surveys to determine user requirements

Within the DMADOV Methodology it is important to require data to determine the critical to qualities (CTQ´s) for the product development. That is why a survey has been created to get insights in different kind of customer requirements. The questions are easy to understand and should be filled in by a range people with different backgrounds. This target audience should at least use chargers daily. See table 3.1 for the survey questions that where send out to the targeted audience. Please see the link below or attachment 1, chapter 2 (measure phase) for more information.

The form can be visited by clicking this link.

Table 3.1 Questions from the survey

Survey question	Type of question
1. What is your age?	Open-ended question
2. What type of charging method do you prefer using?	Multiple choice question
3. What type of cable(s) do you use the most for charging your device?	Multiple choice question
4. Should USB-C be the standard method for charging devices?	Multiple choice question
5. How long should it take before a mobile device is fully charged?	Ratio scale question
6. Do you like to have the option to disassemble a product for repair or recycling purposes?	Multiple choice question
7. How long should the lifespan of a charging device at least be (without failures/manufacturing defects)?	Ratio scale question
8. If a charging device breaks within warranty time, would you contact the company to get a replacement or do you buy a new one for (+/-€20)?	Multiple choice question
9. How quick should a manufacturing/product defect be resolved (including shipping times from and back to the manufacturer)?	Ratio scale question
10. What defines great after-sales service for you? (for hardware-related products, like phones, laptops, televisions, etc.)	Open-ended question
11. What defines a high-quality (hardware) product for you? (material, durability, performance-wise)	Open-ended question

3.2 Research tools

For the project it is important that the charger is well designed and optimised for batch and mass production. Therefor research into design for manufacturing is an important part of this research paper. The research will exist of a combination between quantitative and qualitative research to determine important factors that involve the development of the charger. The qualitative research part will help determine certain material and development process steps. This information will be used in the design phase to determine certain design guidelines. The quantitative research will help determine certain design for manufacturing guidelines and support the key performance indicators. The research will be gathered from multiple sources listed in the bibliography. These sources will help and shape the development of the project.

Conclusion:

A survey has been created and send out to the target audience to determine the user requirements and critical to qualities (CTQ´s). The questions have been sorted on type of questions and the collected data is compiled in the fourth chapter. Other quantitative and qualitative research is gathered from trustable sources. These sources are listed in the main chapters and linked to the bibliography.

Chapter 4: Collected and analysed data

The fourth chapter is about the collected data to determine the charger requirements and key performance indicators (KPI's). In the first paragraph the collected data from the survey is presented in a structured way (4.1). The second paragraph describes the data that was already available from the start of the project (4.2). This are mainly technical prototype drawings and packaging dimensions. The third chapter is about the research into design for manufacturing (4.3). This chapter is important for determining the design guidelines and KPI's. The final paragraph will be an overall conclusion of this chapter.

4.1 Collected data from survey

In this paragraph all the answers from the survey are listed and the raw data has been noted. For the complete data with visualised results please read attachment 2, paragraph 2.1. For the more confined version please see table 4.1.

Table 4.1 Questions and raw data from survey

Questions	Raw Data (n=21)
Average age that filled in the survey	29 years old
What type of charging method do you prefer using?	80% of the people that filled in the survey prefer using a cable charging method over wireless charging
Should USB-C be the standard method for charging devices?	100% of the people that filled in this survey have said that USB-C charging should be the main standard.
How long should it take before a mobile device is fully charged	1.73 hours
Do you like to have the option to disassemble a product for repair or recycling purposes?	50% of the people that filled in the survey never repairs or recycles their own hardware related products.
How long should the lifespan of a charging device at least be (without failures/manufacturing defects)?	4.9 years
How quick should a manufacturing/product defect be resolved (including shipping times from and back to the manufacturer)?	2,1 weeks
If a charging device breaks within warranty time, would you contact the company to get a replacement or do you buy a new one for (+/-€20)?	43% of the survey answers say that they would contact the store or supplier where they bought their product to receive a replacement. 38% of the people will not contact the shop or supplier when a cheaper product fails within warranty time and 19%will both seek contact and directly buy a new one.
What defines great after-sales service for you? (for hardware-related products, like phones, laptops, televisions, etc.)	-To keep the customer updated about new features or products - Fast customer support with good solutions to any possible problems - Fast response, direct replacements, preferably free of charge and shipping. It makes customers more likely to stick to that specific brand or supplier - If the customer service replies fast and offers a few solutions that are fair.
What defines a high-quality (hardware) product for you? (material, durability, performance-wise)	-Nice materials, no offsets like panel gaps in cars that should be even all around, sleek design, smooth to use, easy to understand -Great finishing (I have no material preferred). Minimum 2 years durability. I do not want to worry about the performance, anybody can use the product without reading manuals - The product must accomplish all features expected and to stay working at least several years more.

4.2 Acquired data from eSignus

Circuit board

The second-generation charging board is visible in figure 4.1. This version has changed a lot from the first version, because it was required to be compact enough to fit in a charger. For this version of the circuit board there are made two different versions. The first version (figure 4.1) is the easiest and cheapest one to produce, this version has the USB-C connecter on the top. The disadvantage of this version is that the USB-C port sits a little higher, so it is less compact. Also, the USB-C port has less resistance to the insert of a plug. The second version is more expensive to produce (figure 4.2). This version is about one mm less height on the USB-C part, but the connector thickness is still higher, so it is not recommended to use this part for the production or design of the charger. For more in-depth information about the first and second version, please read attachment 1, paragraph 3.5 (circuit boards).

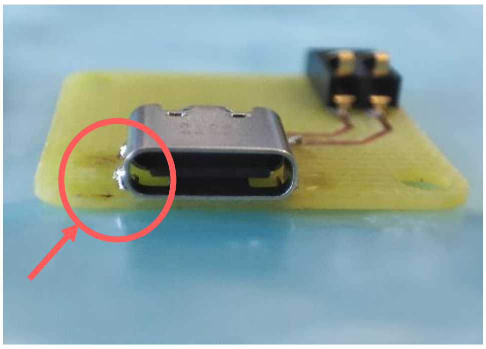
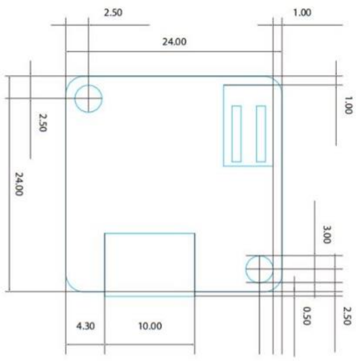


Figure 4.1 Circuit board with USB-C port attached on top



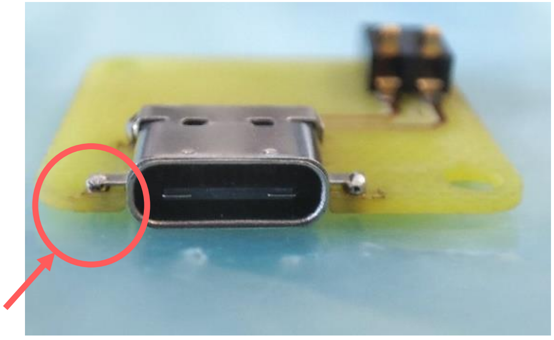


Figure 4.2 Circuit board with inserted USB-C port (cut in board)

Concept drawings of the charger

For the final concept the project team has chosen the design from figure 4.3, because it suits the design of the HASHWallet and the brand well, the screen is not covered, it has all the visual elements that are required, and the charger grips the hardware wallet enough for a tight fit.

Figure 4.3 Final concept drawing of the charger

Placement circuit board:

The circuit board will be housed in the bottom part of the charger. Because the charging points of the hardware wallet are placed on the bottom part of the HASHWallet (figure 4.4). The circuit board has a dimension of 24*24*1mm and has two holes, a USB type C, and a charging connector build on the plate.

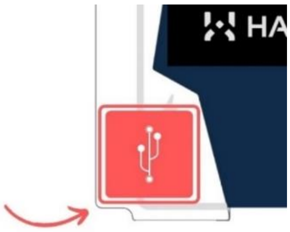


Figure 4.4 Circuit board placement

Dimensions of the HASHWallet

The dimensions of the HASHWallet are (L*W*H) 85.6*54.03*2 mm but for future versions, the thickness of the hardware will decrease from 2 to 1.8 mm. For the exact dimensions, coordinates, specifications, and overall figure see attachment 1, chapter 3.7 (HASHWallet dimensions)

Dimensions of the packaging

One of the requirements of the project was that the charger should fit in the box design that was already designed. So, the maximum size that the charger can have is (L*W*H) 85*54*15mm. The packaging for the HASHWallet can still be adjusted a bit, but the dimensions should not be larger. The dimensions are based on the internal sides for the card slot. The charger will be housed in the bottom part of the packaging, below the HASHWallet. For the exact dimensions, coordinates, specifications, and overall figure see attachment 1, chapter 3 (packaging dimensions).

4.3 Manufacturing research

Additive manufacturing methods unutilized for prototyping and first batch
FDM 3D printer:
For the first prototype units there will be used a FDM 3D printer (see figure 4.5). These 3D printers print on a heated build plate. The coil will turn due the driving motor that brings in the filament to the extruder. The extruder is around 200 degrees Celsius, after the filament runs through the extruder the filament will melt and creates a layer on the plate. This kind of 3D printing is also the most used method (Grames, 2020).


Figure 4.5 FDM 3D Printers

(Mono) stereolithography (M)SLA 3D printer:
For the second type of prototypes, eSignus will use a (M)SLA 3d printer (see figure 4.6). These type of 3D printers print faster and in a higher resolution. But the disadvantage are the smaller build volume, more clean-up work, and the more expensive material it uses to print parts. Instead of using different types of filament spools, SLA printers use different types of resins (Formlabs, n.d.).


Figure 4.6 (M)SLA 3D printer

Selective laser sintering (SLS) 3D printing
For the first 300 charger units the SLS 3D printing method will be utilized (see figure 4.11). The advantages of SLS printing are that the build volume can easily be increased by using larger machines. This step will be outsourced to a local company located in Las Palmas de Gran Canaria. The disadvantages are that there are limited materials to choose from. SLS machines can work with a few polymers, such as nylon and polystyrene. The machine can also handle metals like steel and titanium (Formlabs, n.d.)

Figure 4.7 SLS Printer

For more information about these additive manufacturing techniques see, please read attachment 1, paragraph 3.10

Manufacturing methods
The main method for producing the mass production version of the charger could be by utilizing the injection moulding manufacturing technique. For the first batch it is recommended to get started with a smaller and more affordable injection moulding system that can be used by hand or the SLS additive manufacturing method. For the first version only 300 units need to be produced. Designing and producing an expensive mould will not be feasible for the first batch of 300 units. If injection moulding is a requirement, then it's recommended to use a smaller machine like the LNS Model 150A or a desktop injection moulding machine (see figure 4.8. These machines can be used with an inexpensive resin mould. These moulds are easier and cheaper to produce and can handle up to a few hundred injection shots. Silicone moulds can even be printed with an (M)SLA 3D printer, but it requires flexible resin (+-/€60) that is slightly more expensive to normal resin (+/-€25), that is used for the protypes.


Figure 4.8 Small injection moulding machine

To guarantee a high-quality product for the end consumer it is important the product has a great finish and is built with durability in mind. For this reason, it is not possible to use only a FDM 3D printer to create the final product. Besides the higher material cost and printing defects it does not fulfil the high-quality standards that eSignus would like to have. Therefor there needs to be created a high-quality mould for the charger or the first units need to print with an SLS machine. For the first batch there are three production options. The first option is designing and 3D printing an own resin mould that can be used with an affordable injection moulding machine. The second option would be that a different company that is specialised in injection moulding does the whole moulding and manufacturing part for the first batch 300 units, this will probably not be feasible on such small scale. The last option is to manufacture the products with an SLS machine. Please read attachment 1, chapter 3.11 for more in-depth information about manufacturing options.

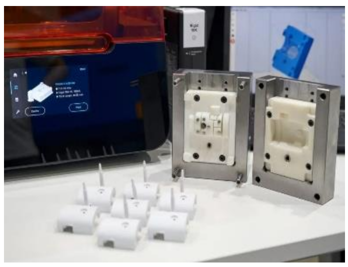


Figure 4.9 Mould development with the use of a resin 3D printer (Formlabs, n.d.)

4.4 Material research

Prototyping materials:
FDM printing:
The prototypes that are made with the FDM printer use polylactic Acid (PLA) as main material. This material is affordable and relatively easy to print with. The PLA printing temperatures are between 190-210 degrees. PLA is also partly biodegradable and is created from renewable biomass products like corn (O'Connell & M. Bohlooli, 2021).

SLA printing:
For the main SLA prints there will be used UV resin from Anycubic. These resins cure when UV light is projected layer by layer. For the development of the mould there will be used flexible resin that has a high temperature resistance (see figure 4.10). This is important because moulded plastic is injected in the resin mould.

Figure 4.10 Flexible 3D printed resin

Manufacturing materials:
List of most common materials used for plastic injection moulding:

- Acrylic or Polymethyl Methacrylate (PMMA)
- Polycarbonate (PC)
- Polyethylene (PE)
- Polypropylene (PP)
- Polyethylene Terephthalate (PETE or PET)
- Polyvinyl Chloride (PVC)
- Acrylonitrile-Butadiene-Styrene (ABS)

However, the list doesn't end here. There are a variety of materials available. That's why choosing the right plastic material for your custom injection molding project is an important decision. Plastic materials look and behave differently based on the characteristics of their chemical makeup. Based on the part's intended application and functionality, important material properties must be considered, such as durability, flexibility, performance, texture, density and color.

It is also essential to look at each material's shrinkage and mold flow rate. Understanding these criteria can mitigate undesirable defects such as warpage, sink marks and color streaks, which can affect the part's dimensions, tolerances and surface finish (icomold, 2021).

Common production materials for injection moulding:
These materials listed below could be used for manufacturing the charger. All the materials have different type of material properties, performances, cost, and aesthetics that need to be taken in consideration when choosing the best material suited for the charger. For more information about these common production materials please read attachment 1, chapter 3.11

1. Polyethylene – PE
2. Polypropylene – PP
3. Acrylonitrile Butadiene Styrene – ABS
4. Polyoxymethylene – POM
5. Polystyrene – PS

Material shrinkage:
Plastic material shrinks after a moulded part cools down after injection. Different type of plastic materials has also different shrink rates depending on resin family (amorphous vs crystalline materials), mould design and processing condition (plastic components, n.d.). Pease, please read attachment 1, chapter 3.11 (manufacturing research) for more information about material shrinkage.

4.5 Design and manufacturing research

There are several important factors to keep in mind while designing injection moulded parts. Because some defects can occur on injected moulded parts, decreasing the overall strength of the part and reducing the overall appearance of injected moulded object. Therefor the most common injected moulded defects are listed below.

Warping:
Warping can occur on a part when certain sections of an injection moulded product cools down (figure 4.15). They will bend due to the stress. Parts with non-consistent wall thickness have more warping issues then parts with consistent walls (Hubs, n.d.). Therefor it's important that the charger consists of uniform wall thickness to prevent the part from warping.

Sink marks:
Sink marks can occur when a part not evenly solidifies (figure 4.12). Small marks on a flat surface may appear. These marks are called Sink marks. This problem can be prevented to use recommended wall thicknesses (Hubs, n.d.).

Drag Marks
Drag marks can occur when plastic is injected in the mould and cools down (figure 4.13). While shrinking it can slide and scrape against the mould, causing drag marks. This issue can be prevented by using draft angles instead of vertical walls (Hubs, n.d.).

Knit lines
Knit lines can occur when the plastic flow meets after flowing around a gap (figure 4.14). This issue will decrease the strength of the part. Parts with abrupt geometry changes or holes are more prone to Knit Lines (Hubs, n.d.).

Short shots
Short shots can occur when air is trapped within a gap where it cannot escape (figure 4.15). This can result in incomplete parts. Therefor it is important to design a mould with ventilation shafts where high pressure air can escape while the injection moulding. Also, parts with thin walls are more prone to short shots (Hubs, n.d.).

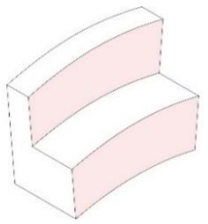


Figure 4.11 Warping (Hubs, n.d.)

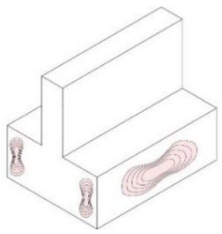


Figure 4.12 Sing marks (Hubs, n.d.)

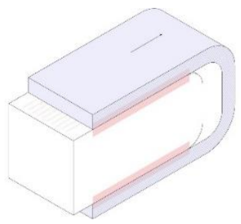


Figure 4.13 Drag marks (Hubs, n.d.)

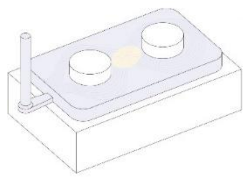


Figure 4.14 Knit Lines (Hubs, n.d.)

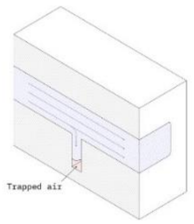


Figure 4.15 Short shots (Hubs, n.d.)

Injection moulding design guidelines
Before designing the charger, it is important to know what type of standard guidelines there are used for designing an injection moulded product. Like minimum outer wall thickness, corners radius, Draft angles, undercuts, and the utilization of bosses/ribs are important factors to keep in mind while designing the part.

Undercuts:
Undercuts are overhang objects like snap fittings without a whole where the object can go through after being injected moulded. Therefor it is important to design the parts without undercuts. If the undercuts cannot be prevented a sliding side-action mechanism (see figure 5.16) can be designed within the mould. But this will make the injection process more complicated and expensive.

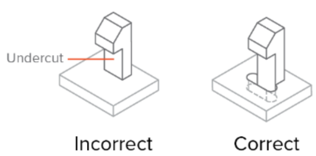


Figure 4.16 Undercuts and overhangs (Hubs, n.d.)

Moving the parting line can also resolve undercuts in a design. When the seam is adjusted like in figure 4.17 the overhang issue is easily mitigated.

The last option to resolve an undercut is by using stripping undercuts (see figure 4.19). These must fallow the fallowing guidelines.

- The stripping undercut must be located away from stiffening features, such as corners and ribs.
- The undercut must have a lead angle of 30o to 45o degrees.
- The injection molded part must have space and must be flexible enough to expand and deform.

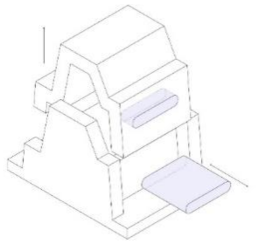


Figure 4.17 Side action mechanism (Hubs, n.d.)

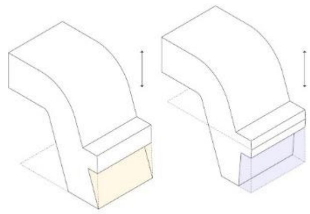


Figure 4.18 Seam line (Hubs, n.d.)

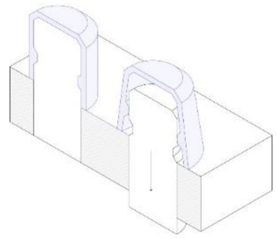


Figure 4.19 Stripping undercut (Hubs, n.d.)

Injection moulding sprue and runner sizes:
The sprue and runners ensure that with injection moulding the part receives the injected plastics. After the plastic is heated up the plastic will move through the sprue to the runners and finally reach the part. The minimum of the sprue diameter is 5mmφ, and normally, use sprue with diameter of 7~8mmφ. To make the flow of the melting resin smooth and even, the runner should be as thick as possible, short, placed well, and each corner should be round so that flow resistance will become smaller (Mitsubishi Engineering-Plastics Corporation, n.d.). For more information about runner and sprue dimensions please read attachment 1, paragraph 3.11 (manufacturing research)

average venting depth for mould design:
The mould vent ensures that left over gases in the mould can escape while being injected at high pressure. Usually vents are around 1.5-6mm in width and 0.02-0.05mm in depth. Material should not enter the vent and the design should be safe for operators to operate the mould (Mold Venting System & Design Principles, n.d.). Please read more about vent design and venting depth per material in attachment 1, paragraph 3.11 (manufacturing research)

Sharp Edges:
Sharp corners put stress on the parts, this can lead to part failure (see figure 4.20). To resolve this issue, parts should have rounded corners. It is advised to have an inner radius Ri=1/2*T. So, the radius should be half the thickness of the wall rounded and the outer radios should be Ri=3/2*T (see figure 4.21). If the design has different wall thicknesses that cannot be avoided, then it is advised to use smooth transitions. These smooth transitions are called chamfers or fillets and must be rounded (see figure 5.4)

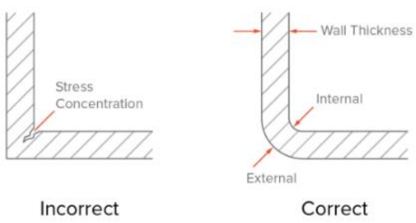


Figure 4.20 rounded and sharp corners (Hubs, n.d.)

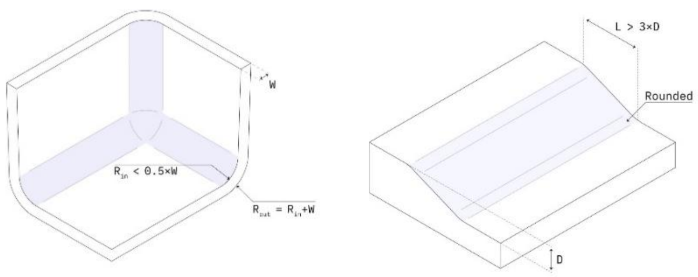


Figure 4.21 Smooth transition (Hubs, n.d.)

Draft angles:

Most product designs have straight outer walls, but straight walls cannot be easily injected moulded. This is because of the release mechanism of an injection moulding machine. Therefor almost all injected moulded parts need to have a slight angle to (see figure 4.21) make the release of the product possible without damaging the sides (Shak Akhrarov, n.d.). [Watch video]() about how to design with draft angles

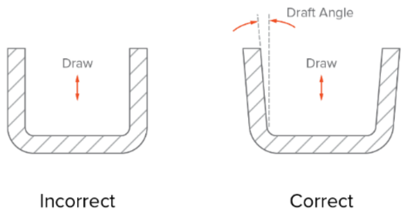


Figure 4.21 Draft angles (Hubs, n.d.)

Utilization of ribs and bosses for structure

Ribs and bosses add a lot of structure to the final product. This improves the durability of the final product. Without any supports the walls could be fragile and collapse. Please read attachment 1, paragraph 3.11 (manufacturing research) for more information about utilization of ribs and bosses.

Wall thickness (design):

The wall thickness of a design is an important factor to ensure that the final product is durable enough and lasts long. By using recommended wall thicknesses while designing the charger will improve the overall lifespan of the product. Please read more about snap wall thickness in attachment 1, paragraph 3.11.

Surface finishing

Injected moulded ABS plastic has a shiny characteristic. But when you apply a texture to a mould it will result in a textured part. This can enhance the aesthetics of the final product and offer extra features like grip, fingerprint, and/or more scratch resistance. But texturing a mould will also increase production complexity, cost, and overall production time. This has to do with the extra steps needed to make the mould and the extra increased cooldown time. Please read more about snap surface finishing in attachment 1, paragraph 3.12.

Joint mechanisms:

The charging circuit board needs to be placed and fitted securely within the charger housing. Therefor a top part is required. The top will secure and protect the charging board from damages. There are different type of joint mechanism options like straight beam, tapered bean snap, snap op, prolonged snap mechanism, ball or cylinder snap, glue joint or screwing (see figure 4.21).

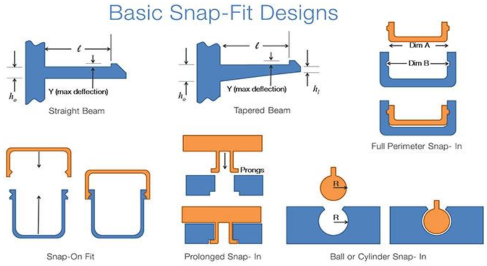


Figure 4.21 Different join mechanism

Conclusion:

Information has been collected in this chapter from the survey that was send out to the targeted audience. Besides that, internal and external research has been compiled to ensure that in chapter 5 the functional and operational requirements could been setup. The data sample from the survey was (n= 21). This means that the data sample was too small compared to the number of users using chargers. This makes data sample not sufficient for a complete quantitative research paper, but the survey helped to receive some interesting information about different customer expectations. The acquired data from eSignus, that was already available internally, helped to ensure that some requirements could be set for chapter five. This information was mainly to determine the final HASHWallet charger design and maximum dimension to ensure that the charger will fit within the pre-designed HASHWallet packaging. A lot of external sources have been collected to collect data around design and manufacturing guidelines. This research helps with determining the requirements and ensure that the final version of the charger can be produced.

Chapter 5: Results from data

The fifth chapter is about the results from the collected data from the fourth chapter. In the first paragraph the voice of the customer has been presented (5.1). The second paragraph is about the customer expectations, and this is visualised with the kano model (5.2). In the third paragraph the design and manufacturing guidelines are set (5.3). In the fourth paragraph the functional and operational requirements are set for the charger designs (5.4). The final paragraph will be an overall conclusion of this chapter.

5.1 Voice of the customer

The voice of the customer and critical to qualities have been mapped with the help of the collected data from the survey (see table 5.1). The CTQ´s are visually presented in attachment 1, paragraph 2.3.

Table 5.1 Voice of the customer

Customer needs	Expectations
Quality	- The customer expects a well-polished product that has a life span of at least 4.9 years. - Accomplish all expected features from customers - Performance should not decrease product lifespan
Durability	- The product should be built durably, so it can handle everyday use.
Customer needs	- The charger needs to have a USB-C port
Expectations	- 50 precent of the customers expect that the device is repairable and recyclable. - Devices should be repaired within two weeks - Great after sales service - A well-polished product
Preferences	- 76 precent of customers prefer using cable charging over wireless charging.
After sales (service)	- Quick solutions/responses when the product does not function well - Helpful and reliable after service - Multiple contact methods (e-mail, phone and/or chat)

5.2 Customer expectations

By using a Kano model (figure 5.2), you can map all the expectations that are likely to satisfy customers. There are three different type of features. The basic features that the charging device must have. Performance based features and attractive features. The most important features are the basic ones. Almost all end-users expect these.

Table 5.2 Kano model charger for the HASHWallet

Nr.	Customer expectations
1	The product is durable
2	The product has no defects
3	The product is user friendly
4	The product functions optimal
5	The product is designed with a fail-safe redundancy
6	The product is designed with poka-yoke in mind
7	The product is as cheap as possible
8	The product is safe to use
9	The product can be dissembled for repair/recycling
10	The product is compact
11	The HASHWallet can be used while charging
12	The product fits in the HASHWallet packaging
13	The LED lights of the HASHWallet are visible while in use
14	The product works with different versions of the HASHWallet
15	The product should charge the HASHWallet faster than with the wireless method
16	The product should have a USB-C port
17	The material used has a great finish.

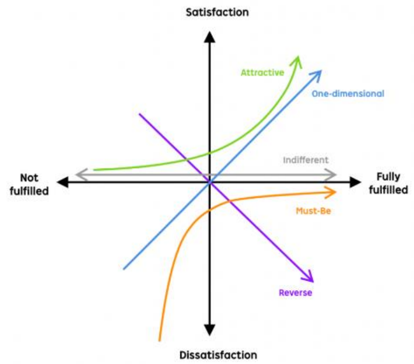


Figure 5.1 Kano model

Basic (must-be) features
1, 2, 4, 5, 8, 11, 13, 16
Performance features (one dimensional)
3, 6, 7, 10, 14, 15
Attractive features
9, 12, 17

CTQ Tree:
The CTQ tree is based on the voice of the customer that was mapped with the help of the collected data from the survey (see figure 5.2).

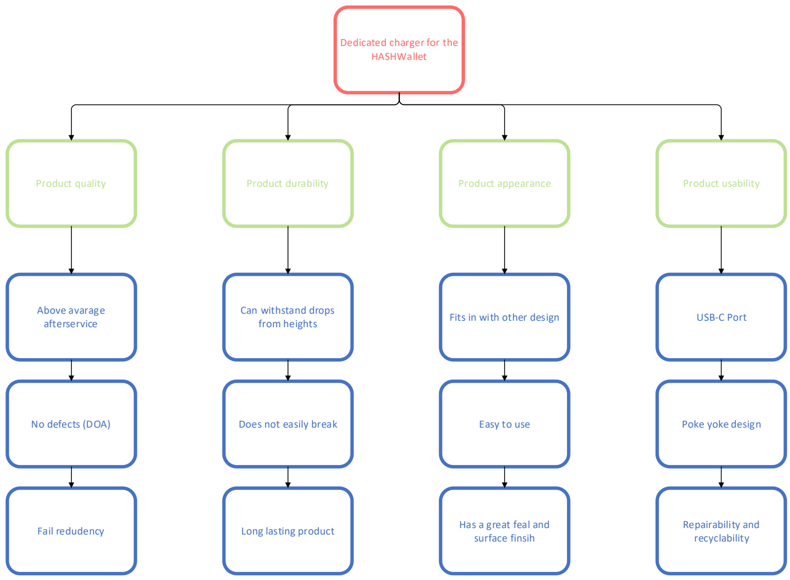


Figure 5.2 Kano model

Customer requirements:
These requirements have been setup after completing and analysing the measure phase. The requirements have been divided in performance, appearance, ergonomics, mechanical properties, manufacturability, Usability, availability, norms/standards, costs, and durability. These requirements (see table 5.3) will be used for the validation process of the charger.

Table 5.3 Customer requirements

	Nr.	***Customer requirements***
		Performance
✓	***1***	*The product functions optimally*
✓	***2***	*The product charges the HASHWallet*
✓	***3***	*The product must faster charge than a wireless charger*
		Appearance
✓	***1***	*The product is precisely finished without loose parts*
✓	***2***	*The material used has a great feeling/finish*
✓	***3***	*The design must resemble a charger*
✓	***4***	*The design must fit with the HASHWallet design*
		Ergonomics
✓	***1***	*The product is easy to use*
✓	***2***	*The product is safe to use*
✓	***3***	*The HASHWallet cannot put in wrongly (Poka-Yoke)*
		Mechanical properties
✓	***1***	*The product must be durable*
		Manufacturability
✓	***1***	*The first version must be produced in a small batch*
✓	***2***	*The second version needs to be able to be produced in medium to large batches.*
✓	***3***	*The product needs to be easy to manufacture*
		Usability and environment
✓	***1***	*The product must be able to withstand external temperature changes between 0-40 degrees Celsius.*
✓	***2***	*The product must withstand different voltage currents.*
		Availability
✓	***1***	*The product must be delivered with the founder's edition HASHWallet*
✓	***2***	*There needs to be after sale service available for the product*
✓	***3***	*The product must be deliverable in countries where the HASHWallet is also available.*
		Norms and standards
✓	***1***	*The product must last for at least two years with included warranty.*
✓	***2***	*The product must be sufficiently tested and have a CE marking.*
✓	***3***	*The product must comply with international legislations.*
		Costs
✓	***1***	*The product needs to be manufactured as affordable as possible, without losing quality standards.*
✓	***2***	*The second version of the charger needs to be cheaper to manufacture than the first version of the charger.*
		Durability
✓	***1***	*The product should on average at least last for 5 years without any manufacturing products*
✓	***2***	*The product must withstand drops from 1,5-meter heights.*
✓	***3***	*The charger must withstand friction from the hardware wallet.*
✓	***4***	*The product must not damage the hardware wallet.*

5.3 Design, material, and manufacturing selection

From the design and manufacturing research that was conducted in chapter 4.5, some design, material, and manufacturing choices needed to be made. Like material selection, wall thickness, charger join mechanisms and manufacturing options.

Material selection

Before choosing a production material for the charger it is important to consider government regulations, the material performance, aesthetics, cost, machinability, intellectual properties, reliability, and the industry standards (see figure 5.4).

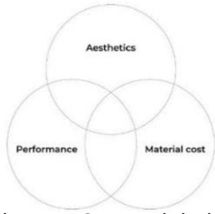


Figure 5.3 Material triangle

Table 5.4 Material selection

Material	*Aesthetics*	*Performance*	*Material Cost*	*Industry standard*	*Total*
Points multiplier	**5**	**5**	**3**	**3**	
Polyethylene – PE	3	3	3	9	84
Polypropylene – PP	3	1	9	3	56
Acrylonitrile Butadiene Styrene – ABS	9	9	3	3	108
Polyoxymethylene – POM	9	3	3	1	102
Polystyrene – PS	1	1	9	3	46

Choosing the optimal material:

Research has shown in the chapter 4.5 that acrylonitrile Butadiene styrene (ABS) is overall the best performing material to produce the charger on a larger scale. The material is an engineering thermoplastic that is widely used in electronic housing, consumer products and different kind of car parts. The material has a relatively low melting point and has a high heat resistance what makes it perfect for the charger. Besides that, the material can easily be used in lower production batches as well, because of its unique characteristics that make it possible to produce with more affordable injection moulding machines. For the lower batch version of the charger nylon will be the best option, because the first 300 units will be produced with an SLS machine.

Wall thickness:

The material for the mass production version of the charger will be ABS, the recommended wall thickness for ABS is 1,1-3,5mm. But how thicker the walls how longer the part needs to cool down, increasing cycle time and production cost. Therefor a uniform wall thickness of 1,5mm has been chosen.

Draft angles

Research has shown that a minimum of 0.5-degree angle is strongly advised. But one to two degrees would work very well in most situations. And three degrees will be required when a light texture is used. Therefor the design will be utilized with a minimum 1,5-degree draft angle on all sides (protolabs, n.d.).

Shrinkage multiplier:

The recommended shrinkage multiplier for ABS is between .004-.008x and the venting depth should be between .0025-.0050mm. (plastic components, n.d.)

Surface finish:

The surface finish for the first two versions of the charger will be glossy, this is the most contrafactive way of producing the part. It is possible to coat the mould with a surface finish to give the charger more grip. This will slightly increase the production cost and cycle time for each part.

Top and bottom connection mechanism:

The most cost-effective solution is gluing the parts together, but when repairability and recyclability is an important factor then a straight snap mechanism or thread mechanism would be the best solution. These connection options will ensure that the internals of the charging board are well protected.

Manufacturing selection:
For the first version batch version where 300 units need to be produced, selective laser sintering (SLS) will be the most effective production method. The Nylon does need to be repainted afterwards to meet customer demand. The mass production version of the charger will be produced by utilizing the injection moulding technique. For larger quantity production 3000+ units it will be the most cost-effective production method.

5.4 Functional and operational requirements

All standard design requirements are listed below, these are based on the measured and analysed research from chapter 4 and 5. The chargers must be verified with these requirements to make sure that the final versions of the charger will function as required (see table 5.5).

Table 5.5 Customer requirements

Functional requirements of the first charger	Design Parameters and KPI´s
The charger will not damage the hardware wallet	Minimal friction (only sides and connecter point)
The max weight of the charger is	<50 gram
Minimal operational temperature	0-40 °C
The charger must have a USB connector	Type C
The dimensions of the charger must fit in the current packaging dimensions	85x 54 x 15 mm (L*W*H)
Material of the charger	Nylon or ABS

Functional requirements of the final charger	Design Parameters and KPI´s
The charger will not damage the hardware wallet	Minimal friction (only sides and connecter point)
The max weight of the charger is	<50 gram
Minimal operational temperature	0-40 °C
The charger must have a USB connector	Type C
The dimensions of the charger must fit in the current packaging dimensions	85x 54 x 15 mm (L*W*H)
Material of the charger	ABS

Operational requirements of the first and final chargers
The charger must be easy to use
The charger must work with the new HASHWallet design
The charger will not damage the hardware wallets
The charger is portable and easy to carry
The LED indication lights are not obstructed while charging
The battery health is not influenced by the charging method (under normal conditions)
The dimensions of the charger must fit in the current packaging dimensions
The charger does offer minimal to no wear on the HASHWallet
The charger must charge faster than using the wireless charging method
The charger must be functional while charging
The charger must be able to be manufactured

Conclusion:

The results from the collected data from chapter four has been analysed in chapter five. The voice of the customer and customer expectations have been created from the results from the survey and conducted research. These expectations have been mapped in a Kano mode. Within this model it was clear that certain requirements, like no-defects, durability, safety, and a USB-C port should be included with the charger to ensure customer satisfaction. In the third paragraph the design, material, and production methods where selected. Research has shown that SLS-printing method is for the first (small – 300 units) batch version the most effective option. Injection moulding will be the best manufacturing option for the second mass production version of the charger. The material for SLS printing will be nylon, this white material needs to be painted after being laser sintered to ensure the finish customers expect. For the mass production version ABS will be used. This material comes in a variety of colours and has great properties that align with customer expectations and the material ranked best from the matrix in paragraph 5.3. In the final paragraph of this chapter all the operational and functional requirements have been mapped. These requirements and KPI´s will be tested on the final designs.

Chapter 6: First charger design

The sixth chapter is about the design phase of the first charger. In this chapter the first low batch version of the charger is fully designed. The first paragraph is about the 3D software tools used to design the first version (6.1). The second paragraph is about the first design process (6.2). The third paragraph is about choosing the final design (6.3). The fourth paragraph is about the final protypes and the validating process of the final protype (6.4). The fifth paragraph will show the entire prototype process (6.5). The final paragraph will be an overall conclusion of this chapter.

6.1 3D software tools

For the design of the charger there will be used multiple 3D tools to design, visualize and prototype the charger. The 3D tools used will be Autodesk 3ds max, Fusion 360 and multiple slicing software's for 3D printing the prototypes. For sharing the files .FBX, .OBJ, .STL, and 3mf. files will be the main standard.

3ds Max:

Autodesk 3ds Max will be used for designing the first prototypes and for creating the 3D visualisations. After that the designs will be created within Autodesk fusion 360.

Fusion 360

Fusion 360 will be used for creating the final 3D designs, the software made for creating accurate manufacturing products.

Cura, Chitubox and lychee slicer software

Cura, Chitubox, and Lychee will be used as slicing software tools to 3D print the prototypes. With the help of slicer software's, a 3D printer knows how to print a 3D model by fallowing the paths or adjusting the LCD screen to cure resin.

6.2 First design process

The first 3D visualisation was created by an external motion graphic designer that supported the project team, for reference see figure 6.1. The visualisations and 3D designs are made in Modo. The 3D designs were made to analyse if it is possible to place al the electronic parts within the charger and how the charger should look.

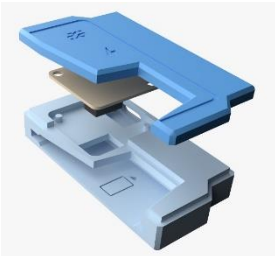


Figure 6.1 first 3D visualisation

First 3D prototype

The first 3D models were printed with an SLA 3D printer to check if the model is also working and if the HASHWallet is charging correctly (see figure 6.2). The charger charged the HASHWallet, but there were some problems with the dimensions (see figure 6.3), so the card did not fit in well. Besides that, the LED lighting was not easily readable and the USB-C port on the circuit board did break after a few times of using the charger (see figure 6.4). This problem was caused by having too much room for the USB-C connection port. Therefor it was important that the 3D model needed to be adjusted.

Figure 6.2 First prototype charger

Figure 6.3 Dimension issue

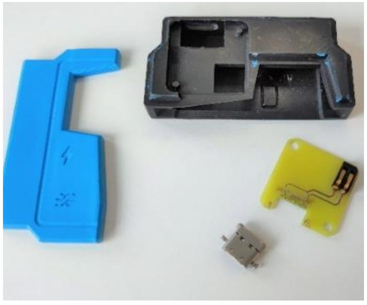


Figure 6.4 Broken charging board

Second 3D model

After creating a new 3D model from scratch, it was important that the design had some improvements over the first test version that was created by the motion 3D designer. This version should be created as a charger that can be used within the office for testing purposes and on events. The new project team was responsible for the newer version and it was created within Autodesk 3ds max (see figure 6.4) a different program then the external 3D designer used, but the two programs are very similar. The visualisation renders are done with a different plug-in render engine that works with Autodesk 3ds Max.

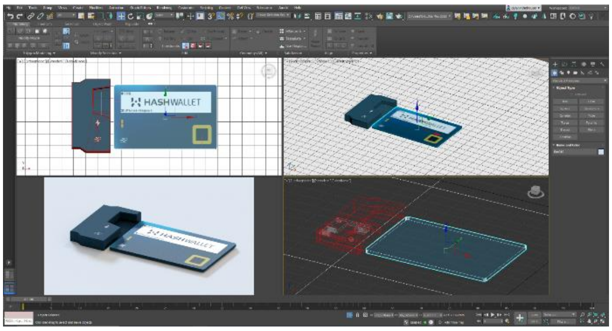


Figure 6.4 3ds max viewport

As mentioned before the 3D visualisation renders are made with a render engine plug-in within 3ds max. With the help of 3D visualisations, it is easier to see how the final product/result will look. That is why 3D visualisations are common to use within product development, see figure 6.5 for the first results.

Figure 6.5 Visualisations of the first test version

After checking the visualisations and dimensions it was clear that the problem with the LED indication lighting was still not resolved and that the model could more resemble the first concept design. After this the 3D designer has changed the model a bit so that the LED indication lighting is visible and that the design resembled more the concept version of the card.

For these design changes it was necessary to change the bottom part of the charger where the circuit board is placed. This makes the design more fragile, because the outer layer of the charger is thinner (see figure 6.6). Therefor it is important to check if the protype is strong enough.

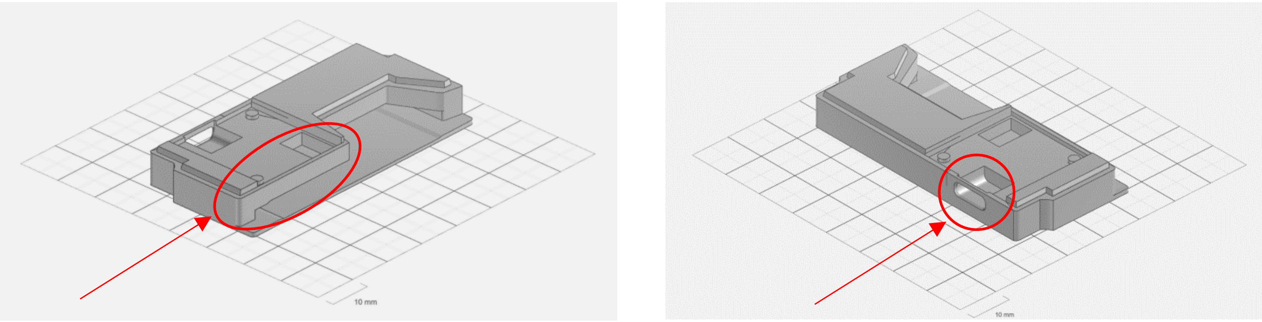


Figure 6.6 Fragile parts of the design

In figure 6.7 you see the changes that have been made to the 3D model. The newer version resembles more to the prototype drawing, the top part can be connected to the bottom part and LED indication lights are better visible. But this comes with the disadvantage that the design is more fragile than the previous version.

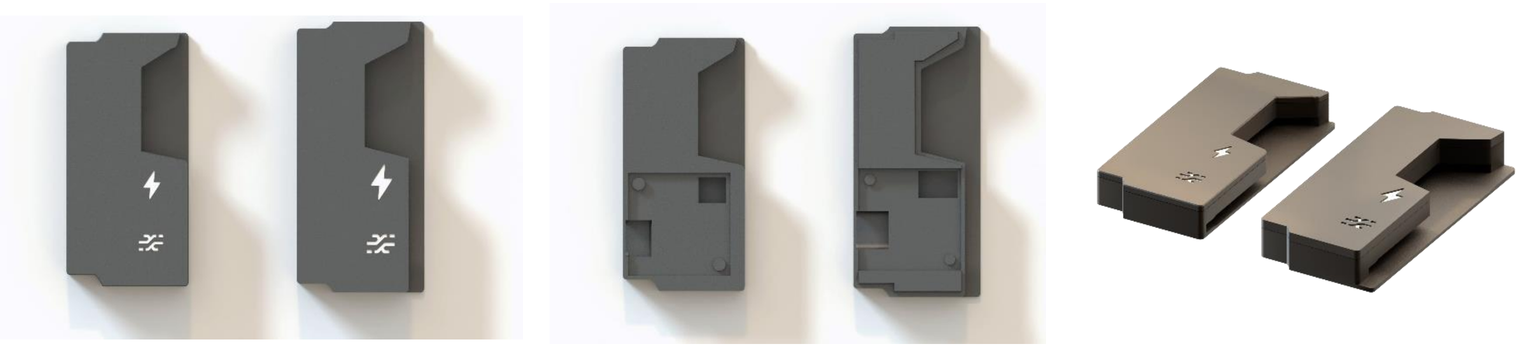


Figure 6.7 Design changes for the LED indication lights

6.3 Choosing final design

After designing many different versions of the chargers. It was necessary to choose the best design for the first batch. The second version will be redesigned to make sure it is ready for mass production. In total there are designed four different versions. For the first and second version see figure 6.8, for the third version see figure 6.9, and for the final and fourth version see figure 6.10.

Figure 6.8 First and second version of the charger

Figure 6.9New design, third version renders

Figure 6.10 New design, fourth version renders

The project group has decided that the more compact design from figure 6.9 was the best solution for the first version. This concept version was as compact as it could get with the current charging board, the card slides in and out easily, the protype did function well and the LED indication lights where easily visible (see figure 6.9).

Final version for SLA and SLS production

For the SLS and SLA printing part there where made some small changes to the model. These updates where mainly focused on aesthetics and the USB-C connection port (see figure 6.11). For aesthetics there was added a card insert icon and card indication line. So that consumers know exactly how to orientate and place the card within the charger. Besides that, some slight adjustments have been made to the USB-C port to ensure that it fits securely.

The charger will also be painted black, therefor the 3D designs have been changed to a darker grey/black colour. This makes validating process more efficient. The final version is rendered below (see figure 6.12).

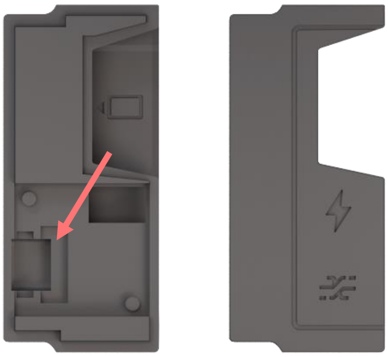


Figure 6.11 Charger chassis 3D render

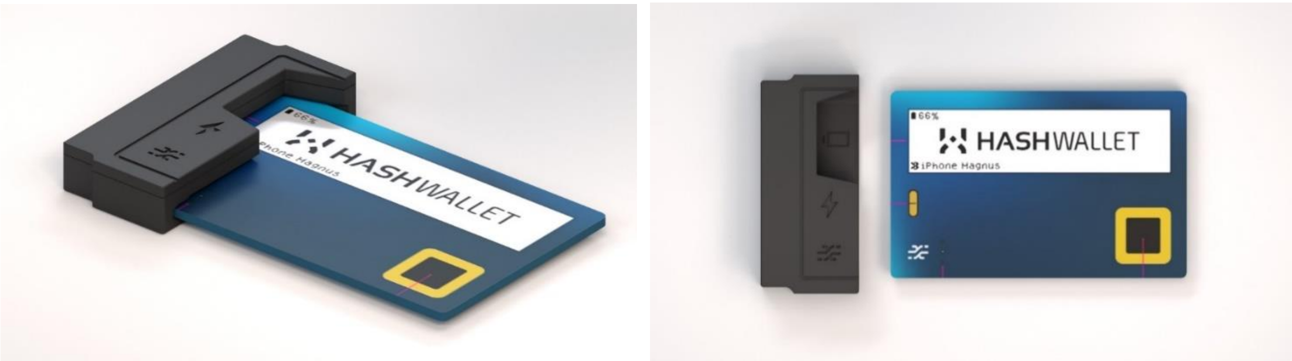


Figure 6.12 Final Renders

6.4 Final prototypes and validating process

The resin prototypes came a long way from the first print. At the start prints had some defects, because working with an SLA printer is quite different from working with an FDM printer. After two days the prints became better by making some slight adjustments to the printing position and switching form slicing software. Alexis helped the project team by giving some feedback and advice about slicing software's. Prints improved, after switching to a different slicing software (Lychee slicer 3). With this software it was easy to move the printing supports away from the main print (see figure 6.13). This resulted in less clean-up work and better print quality.

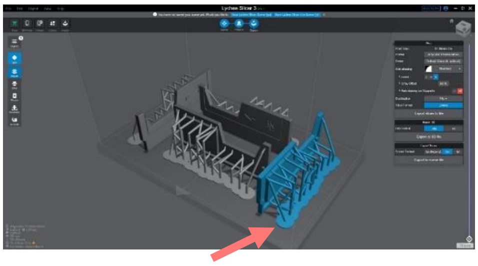


Figure 6.13 Lychee 3 slicing software (support structures)

Difference early and updated prints:

The difference between the first and final prints are quite significant (see figure 6.14). At first the prints where far from perfect and after a week of trial and error, the prints had improved. There were added some small appearance and minor dimension changes to the model after the prototype prints had improved.

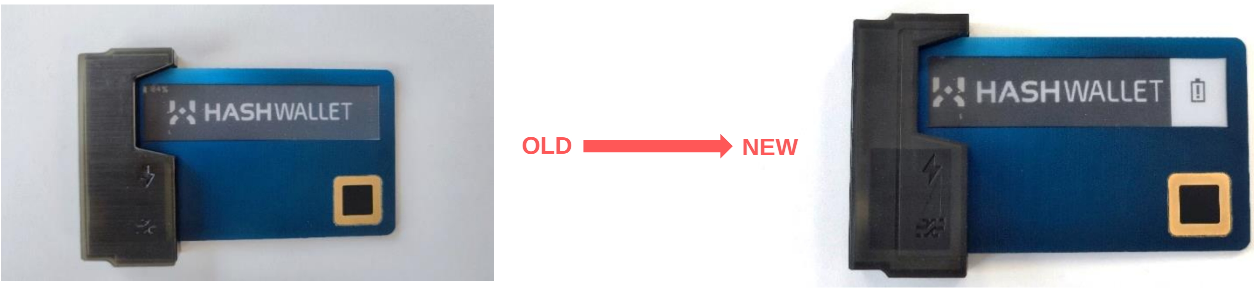


Figure 6.14 Early version resin print – updated version resin print

Painting the prototypes:

Resin is translucent from itself as you can see from figure 6.14. To meet client expectations a black paint layer was applied by spraying mate black colored paint at the prototype. See figure 6.15 for the result.

Figure 6.15 painting the chargers

Prototype test run

After printing many prototypes, the design was ready to be tested and verified. In figure 6.16 you see the prototype charging the HASHWallet. This meant that the prototype was fully operational and could be used at certain events and within the eSignus team. After this step about ten prototypes will be created for the team and event use cases. Besides that, one prototype will be shipped to the packaging designer and manufacturer. This company will adjust the packaging to fit the charger within the packaging of the HASHWallet. After this step the outer dimensions of the first batch version cannot be changed anymore. Smaller internal changes can be made to make to improve the first batch version of the charger. Bellow there have been added some extra references of the final protype charger (see figure 4.31).

Figure 6.16 Testing the prototype charger

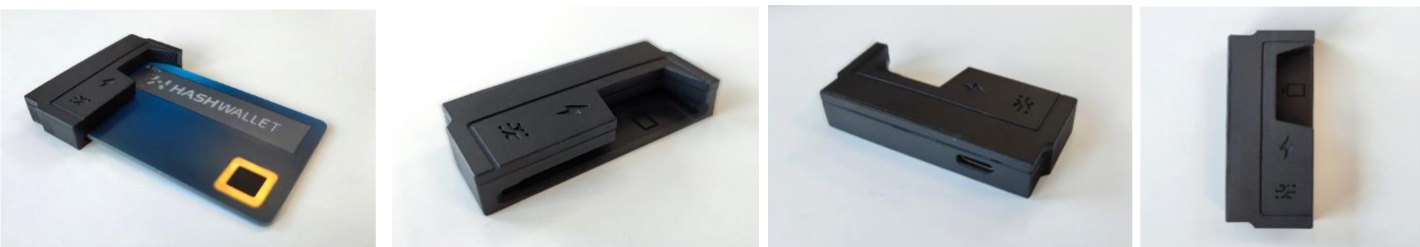


Figure 6.17 Additional images of the prototype charger

Final charger visualisations

The final charger designs are displayed in figure 6.18. The design operates fully with the newer versions of the HASHWallet. See the validating process in the attachment, paragraph 4.18. Only small changes have been made to the design, like the connection part of the top see red circle in figure 4.32. This change to the design makes the part sturdier.

Figure 6.18 Final charger visualisations

Validating final design – Key performance indicators check (KPI´s)

The project team validated the final prototype in this paragraph, see table 6.1 for the requirements with validation. In figure 6.19 you see the charger with the USB-C port and the final test of the charger. The HASHWallet is charging, and the indication lights are visible while charging. Please read table 6.1 for the full verification check

Figure 6.19 testing final prototype

Table 6.1 Verification check

Check	Functional requirements of both chargers	Design KPI´s	Verification check
✓	The charger will not damage the hardware wallet	Minimal friction (only sides and connecter point)	The charger has minimal friction and there are no marks when using the charger often. This is tested by the team.
✓	The max weight of the charger is less then	<50 gram	The charger weights around 30 grams with the charging board and after painting.
✓	Minimal operational temperature	0-40 °C	The charger does not get hot while charging the HASHWallet.
✓	The charger must have a USB connector	Type C	The charger has an USB-C port
✓	The dimensions of the charger must fit in the current packaging dimensions	85x 54 x 15 mm (L*W*H)	The charger fits in the current designed packaging.

Check	Operational requirements of the first batch charger	Verification check
✓	The charger must be easy to use	The charger is easy to use and has markings on it to guide the user.
✓	The charger must work with the new HASHWallet design	The prototype charges and fully functions with the HASHWallet.
✓	The charger will not damage the hardware wallets	The charger does not damage the HASHWallet under normal use.
✓	The charger is portable and easy to carry	The charger is very compact ant easy to carry around.
✓	The battery health is not influenced by the charging method (under normal conditions)	The battery charges normally, no operational error detected while testing for a week.
✓	The dimensions of the charger must fit in the current packaging dimensions	The charger fits within the maximal set packaging dimensions.
✓	The charger does offer minimal to no wear on the HASHWallet	The charger does offer minimal friction to the HASHWallet. Only the sides tach the hardware wallet. Top bottom is lifted to prevent scratching the device.
✓	The charger must charge faster than using the wireless charging method	The charger offers current flow to the HASHWallet what results in better and more reliable charging over wirelessly charging the device.
✓	The charger must be functional while charging	The charger can be used while charging the device, screen and fingerprint reader are free from obstruction.
✓	The LED indication lights are not obstructed while charging	The LED indication lights are clearly visible while charging the device.
✓	The charger must be able to be manufactured	The charger can be manufactured with the SLS-printing method.

6.5 Prototyping process

First FDM protypes:

The second 3D protype is printed with a 3D printer from a team member that works with the hardware development team. The 3D print resembles a prototype but has some issues like a lower print quality then from a (M)SLA 3D printer, because this model is printed on a FDM printer.

Figure 4.20 Second 3D prototype (FDM printer)

Solving prototype issues:

To increase the development speed of the project and prototype quality, it was advised to invest in an affordable (M)SLA 3D printer for in the office in Las Palmas de Gran Canaria, this has been approved by Daniel (project lead). With this addition the prototypes do not have to be shipped weekly around what will improve the development speed and on the long run will save transport costs as well. After the 3D printer arrived in the office of Las Palmas many prototypes were created for the first version of the charger, to ensure that the final version would function optimal. Please see the whole prototyping process in figure 6.20. For more information about the design and protype phase, please read attachment 1, chapter 4.

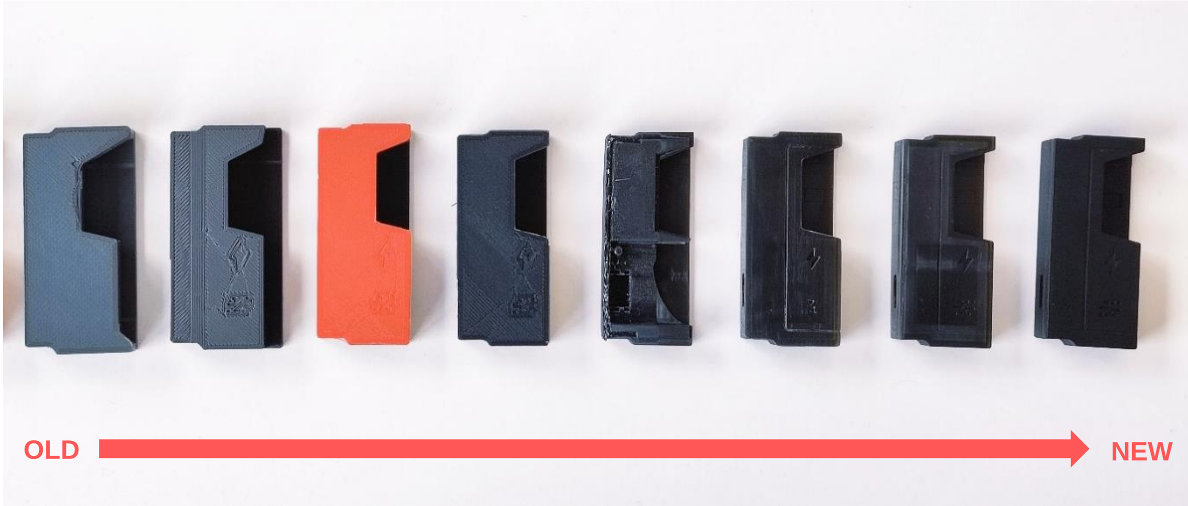


Figure 6.20 prototype progress

Conclusion:

There are made many different designs and prototypes to ensure that the final protype does fulfil the customer and client expectations. The process has been mapped within these paragraphs. At first it was important to determine the tools that where needed to create these designs. The selected 3D tools are 3Ds max and fusion 360 for modelling the 3D models. For slicing the 3D parts, Cura, Chitubox, and Lychee were used to utilize 3D printers for the prototyping process. After using these software tools, it was necessary to create multiple models to choose from. The final model that was chosen to be the main design fulfilled all the requirements that where set in chapter 5.4. After the final design was chosen, the final protype was made to test it with the HASHWallet. The charger was ready after making a few small changes to ensure that the circuit board fits perfectly within the charger chassis. After this step the charger got validated with the functional and operational requirements and it passed on all the requirements. Finally, the chapter closes with an overall view of all the different protypes that where created.

Chapter 7: Optimize design for mass production

Chapter seven is about optimizing the first version of the charger so it can be mass manufactured. Paragraph one will be about how the design can be optimized (7.1) The second paragraph is about two different design options that allow mass manufacturing (7.2). The third chapter is about the final design and prototype (7.3). The fourth paragraph is be about the verification of the design (7.4). The final paragraph will be an overall conclusion of this chapter.

7.1 Charger optimization

As noted earlier in the research phase of the project it was clear that the final version of the charger design needed to be optimised for injection moulding. This production technique will be the most optimised production method on large scale. The charger needs to be designed with the manufacturing guidelines to keep the custom mould cost down as much as possible. Therefor it was necessary to make fundamental changes to the design. The part needed to exist of minimal three pieces to avoid any undercuts. Besides that, it was important to have drag angles, so the parts could be removed from the mould.

7.2 Choosing design

Two different versions are designed, and 3D printed to test which of the two versions would be optimised to all design for manufacturing guidelines.

The first option is the USB-C port is shared with the top part is shown in figure 7.1 The advantages are that this option is easy to assemble. Besides that, the seam lines are straight around the charger. The disadvantage is that only one colour can be used for the main chassis of the charger.

The second option has the USB-C port split in half and shared with the bottom part of the charger (see figure 5.2). The advantage with this method is that the top part can have a different colour from the bottom part of the charger as seen in the figures (7.2). The disadvantage is that the seam line is not fully aligned with the charger. Because there needs to be a slight angle placed to mitigate the minimum thickness of the charging board. Besides that, the USB-C area could be fragile after splitting it in half.

Chosen design:

After a poll that was conducted within the company the second design was chosen to improve on. Most of the project members that voted liked the idea that the top part could have a different colour, making the final charger design more interesting.

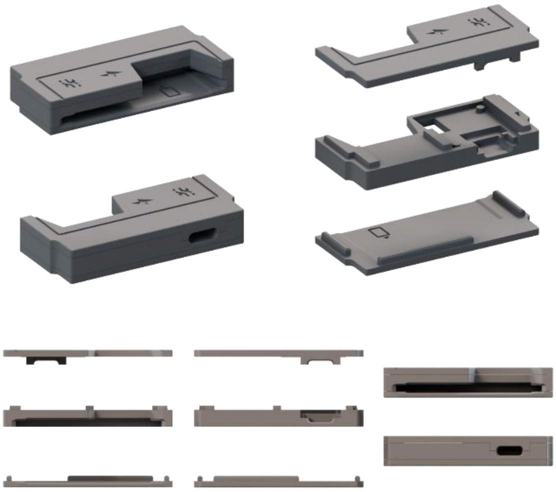


Figure 7.1 Second version for the mass production charger chassis

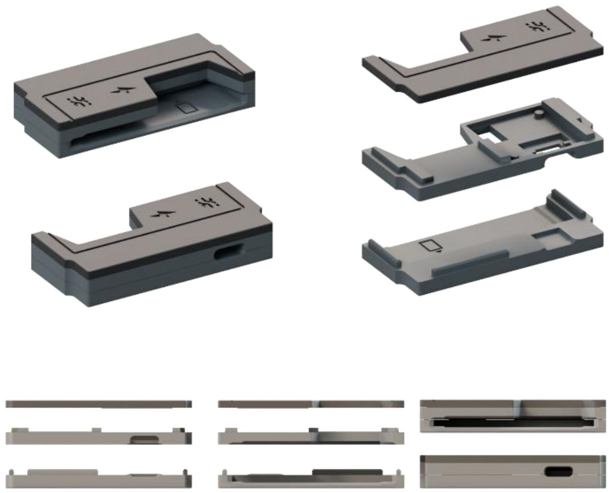


Figure 7.2 Second version for the mass production charger chassis

7.3 Final design and prototype

For the redesign of the charger, it is recommended to have uniform walls. Besides that, the charger needs to be designed with design for manufacturing guidelines. These guidelines are described in chapter three.

Design in fusion 360

The final version of the charger has been made in fusion 360, with this software it was possible to design the charger with the necessary design with manufacturing guidelines that were determined in the analyse phase. In figure 5.4, you see the designed version in fusion 360.

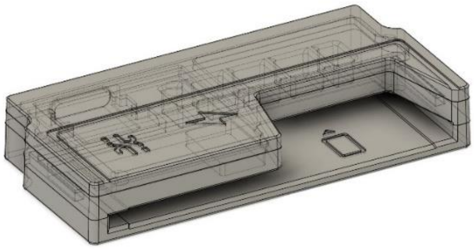


Figure 5.4 Final mass production HASHWallet charger

Testing final prototype:

In figure 5.5 you see the prototype charging the HASHWallet. This meant that the prototype was fully operational and could be manufactured. Still there is much room for improvement regarding the manufacturing side of the design. The middle part of the charger is too thin. This can be resolved to choose a different design where the top part is integrated within the middle part like in figure 5.1.

Figure 5.5 Final mass production HASHWallet prototype

Final visualisations

In figure 5.6 you are able to see the final 3D visualisations of the charger. The visualisations are created within 3ds max.

Figure 5.6 Final HASHWallet charger 3D visualisations

7.4 Validating the charger

The project team validated the final prototype in this paragraph, see table 5.1 for the requirements with validation.

Table 5.1 Validation of the requirements

Check	Functional requirements of the final charger	Design Parameters and KPI´s	Verification check
✓	The charger will not damage the hardware wallet	Minimal friction (only sides and connecter point)	The charger has minimal friction and there are no marks when using the charger often. This is tested by the team.
✓	The max weight of the charger is	<50 gram	The charger weights around 25 grams with the charging board and after painting.
✓	Minimal operational temperature	0-40 °C	The charger does not get hot while charging the HASHWallet.
✓	The charger must have a USB connector	Type C	The charger has an USB-C port
✓	The dimensions of the charger must fit in the current packaging dimensions	85x 54 x 15 mm (L*W*H)	The charger is smaller than the maximum design parameters.
✓	Material of the charger	ABS	Material can be manufactured with ABS material.
✓	Designed with manufacturing guidelines	Draft angles, no overhangs and uniform walls	The charger is designed with draft angles, has no overhangs and overall, the walls are uniform, but this can be improved.

Check	Operational requirements of the first batch charger	Verification check
✓	The charger must be easy to use	The charger is easy to use and has markings on it to guide the user.
✓	The charger must work with the new HASHWallet design	The prototype charges and fully functions with the HASHWallet.
✓	The charger will not damage the hardware wallets	The charger does not damage the HASHWallet under normal use.
✓	The charger is portable and easy to carry	The charger is very compact ant easy to carry around.
✓	The battery health is not influenced by the charging method (under normal conditions)	The battery charges normally, no operational error detected while testing for a week.
✓	The dimensions of the charger must fit in the current packaging dimensions	The charger fits within the maximal set packaging dimensions.
✓	The charger does offer minimal to no wear on the HASHWallet	The charger does offer minimal friction to the HASHWallet. Only the sides tach the hardware wallet. Top bottom is lifted to prevent scratching the device.
✓	The charger must charge faster than using the wireless charging method	The charger offers current flow to the HASHWallet what results in better and more reliable charging over wirelessly charging the device.
✓	The charger must be functional while charging	The charger can be used while charging the device, screen and fingerprint reader are free from obstruction.
✓	The LED indication lights are not obstructed while charging	The LED indication lights are clearly visible while charging the device.
!	Charger can be manufactured	From the simulation results the charger should be able to be injected moulded. But is recommended to redesign the second part or choose the other design from chapter two.

Conclusion

Before the charger could be mass-produced it needed to be split in three parts. These parts must be designed with the manufacturing guidelines in mind. The design where the USB-C port is split in half was chosen, after creating two different designs with their own advantages and disadvantages. The reason for choosing this design was that most of the project members voted for this version to be chosen. With this version the top part of the charger could be injected moulded with a different colour, making the charger more unique and aesthetic wise more interesting to look at. But the disadvantage was that charger would be more fragile around the USB-C area. This was noticeable while testing and validating the charger against the requirements. But the charger checked all the other validation marks.

Chapter 8: Manufacturing process setup and validation

Chapter eight is about the manufacturing and process setup of the designs. Paragraph one is about how to operate the SLA printer (8.1). The second paragraph is about the process setup of the internal manufacturing part of the first charger (8.2). The third paragraph is about manufacturing setup for the mass production version of the charger. This paragraph includes the bill of materials, injection moulds and injection simulations (8.3). The final paragraph will be an overall conclusion of this chapter.

8.1 Operating SLA printer

To create better detailed protypes eSignus has invested in an SLA 3D printer. This printer is installed on the 3rd of November in the office of Las Palmas de Gran Canaria. It is placed in a separate well-ventilated room so that it does not distract anyone in the office. Besides this resin fumes are quite unpleasant and dangerous to work with. Therefor it was advised to place it in a separate well-ventilated room.

Figure 8.1 SLA printer

To maintain a secure and safe work environment there has been invested in some safety gear. Like safety glasses, gloves, plastic containers, tweezers, and face masks. While working with the SLA printer it is recommended to fallow the fallowing process steps that are noted in attachment 1, chapter 4.12. These are created to make sure everyone knows how to operate the printer safely.

8.2 Internal manufacturing

SLA printing process

All SLA printing steps are displayed in figure 8.2. The steps are noted within a process map and the additional images can been seen in attachment 1, chapter 4.13. these images can support the process. With the safety guidelines from table 8.1 and by fallowing the process map, you are able to safely operate the (M)SLA printer. Please keep in mind to wear gloves, a mask and goggles while working with the resin.

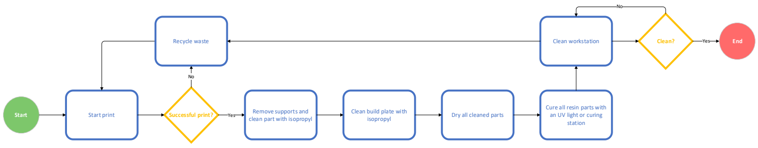


Figure 8.2 SLA printing process

Circuit board placement process

The circuit placement steps are displayed in figure 8.3. The steps are noted within a process map.

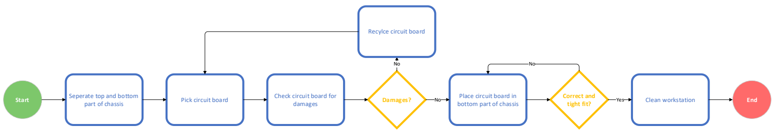


Figure 8.3 Process gluing protype charger

Gluing process

All gluing steps are displayed in figure 8.4. The steps are noted within a process map and the additional images can been seen in attachment 1, chapter 4.14. Please keep in mind to wear gloves while working with strong glue.

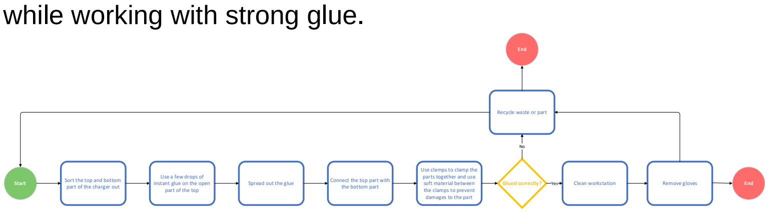
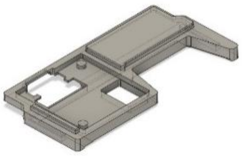
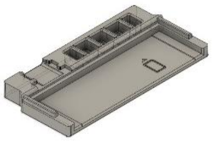
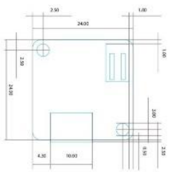


Figure 8.4 Process gluing protype charger

8.3 Manufacturing setup for mass production

Bill of materials:
The mass production of the charger will exist of three four parts. The first three parts will consist of the injected moulded parts. Within this chassis the circuit board (last part) will be placed. The circuit board will consist of a USB-C part and circuit board, but the part will be bought as one piece from a different supplier.

Table 8.1 Verification check

Quantity	Parts	Dimensions	Manufacturing process	Cycle time (injection moulding)
1x Top part chassis		28.5x60x2.4mm (lxwxh)	- Injection moulding - Assembly - Gluing	17.7 seconds (please see injection moulding simulations)
1x middle part chassis		28.5x60x4.9mm (lxwxh)	- Injection moulding - Assembly - Gluing	34.8 seconds (please see injection moulding simulations)
1x Bottom part chassis		28.5x60x5.7mm (lxwxh)	- Injection moulding - Assembly - Gluing	48 Seconds (please see injection moulding simulations)
1x Circuit board		24x24x1mm (lxwxh)	- Sourced externally - Placed within chassis	-

Designed injection moulds:
For reference there are three different moulds designed within fusion 360 (figure 8.5). These moulds each house two times one part. These parts are connected to the runners where the moulded plastic will be injected trough. It is also possible to choose a family mould where all the three parts will be injected within one mould. This can decrease total mould design costs. But filling can be unbalanced, deceasing moulding quality (plastopialtd, n.d.).

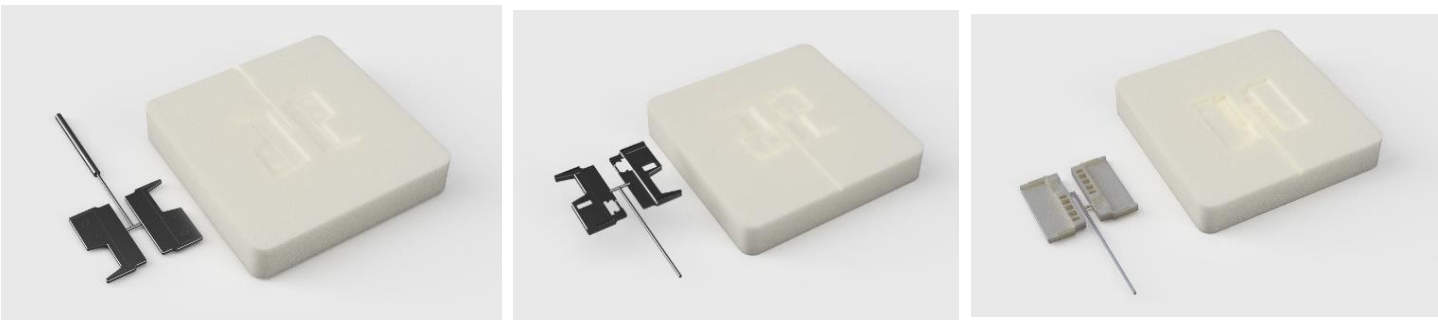


Figure 8.5 the three different mould designs, created within fusion 360

Manufacturing simulations

These simulations are created within Fusion 360. With the help of these simulations, it is easier to predict how the part will be injected moulded and what the strong and weakness are of each part. Besides that, it calculates the cycle time for each part. The simulations are run with ABS material called TFX 210 and the melt temperature is set to 230 degrees Celsius. Shot time and pressure is set on automatic. These simulations with results can be checked within the fusion 360 file.

Part 1: Top part chassis

The fill confidence of the top part of the cassis is overall good. This means that the part is easy to fill with the utilization of injection moulding. There are some parts where there can occur minor difficulties please see figure 8.6 For the simulation results. The total injection moulding time will be 17.7 seconds, this time includes cooling and ejection time. Please see attachment 6.4 for full resolution simulation images.

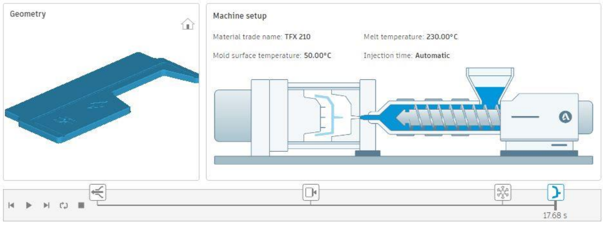
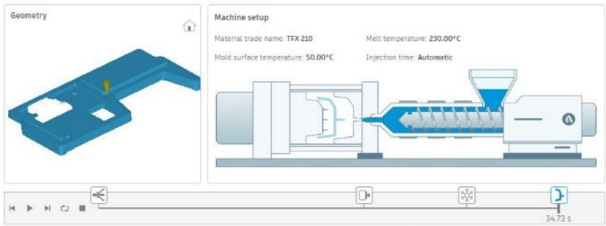


Figure 8.6 Injection mould simulations (part 1)

Part 2: Middle part chassis

The fill confidence of the middle part of the cassis is less than ideal. This means that there is a small area where the part cannot be correctly injected moulded. The issue is that the part is too thin to allow the flow to easily pass through the part. please see figure 8.7 for the simulation results. The total injection moulding time will be 34.8 seconds, this time includes cooling and ejection time. Please see attachment 6.4 for full resolution simulation images.



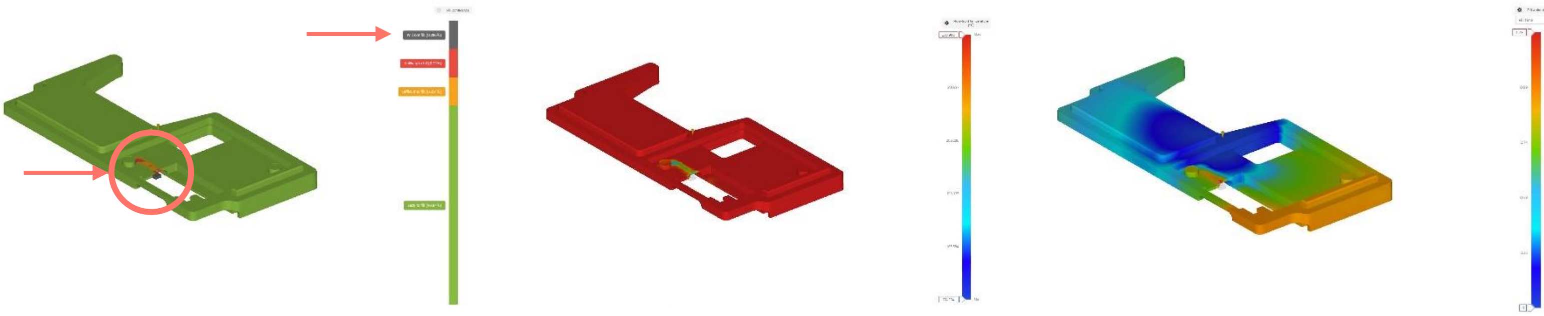
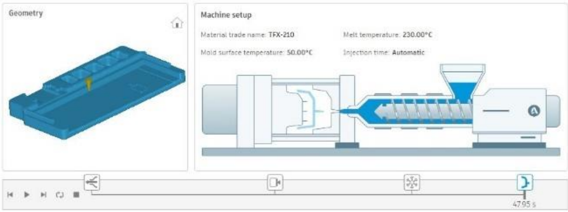


Figure 8.7 Injection mould simulations (part 2)

Part 3: Bottom part chassis

The fill confidence of the top bottom of the cassis is overall good. This means that the part is easy to fill with the utilization of injection moulding. Please see figure 8.8 for the simulation results. The total injection moulding time will be 17.7 seconds, this time includes cooling and ejection time. Please see attachment 6.4 for full resolution simulation images.



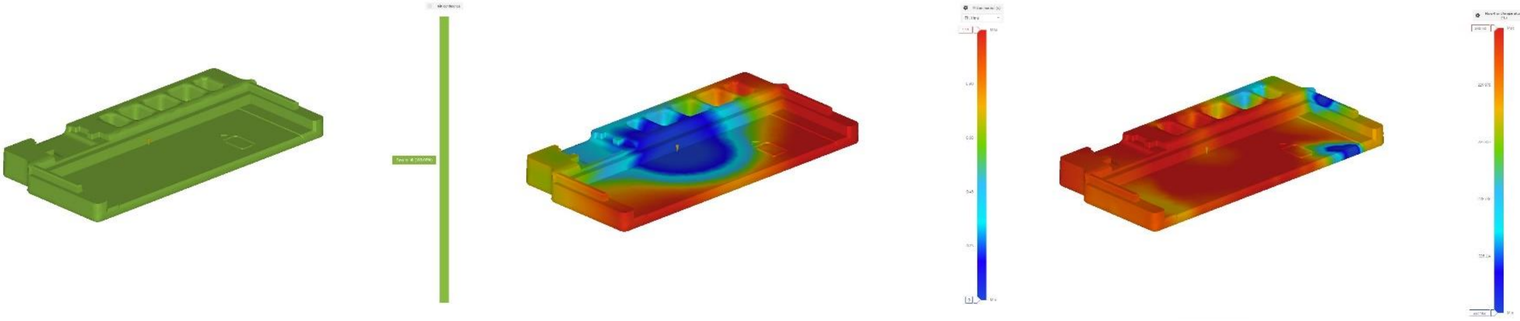


Figure 8.8 Injection mould simulations (part 3)

Simulation results when choosing the other part design:

As mentioned in chapter 7.2 where the two designs were checked and chosen by the project team it was clear that the other design where the USB-C part is integrated within the top part of the chassis would be stronger and easier to manufacture. From the simulation results it becomes that this version of the charger will have a better final injection outcome, because the middle part will not have a short shot. This means that an area of the part is difficult to fill with moulded plastic, decreasing the quality of that part. Please see attachment 6.4 for full resolution simulation images.

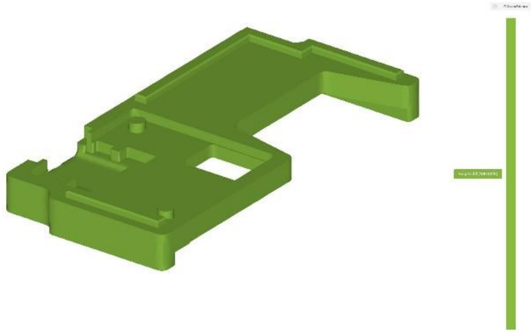


Figure 8.9 Different design simulation check

Conclusion:

While working with the SLA machine it is upon the most importance to work with gloves, safety goggles, and mask on. The resin that is used for printing is harmful. Therefor it is important to fallow the safety rules and regulations. The first batch of the charger will be crafted with the SLS-printing method and consist of two parts. The bottom and top part. These parts have less design for manufacturing guidelines then the mass production version of the charger. The mass production version of the HASHWallet charger will be manufactured with injected moulding. For this reason, the chassis needed to consist of minimal three parts. These parts where designed and tested within fusion 360. From the simulation software it was clear that the other design from chapter 7 would have a better-quality outcome. The middle part of the chassis is now fragile around the USB-C area. This can lead to quality issues. Therefor it is recommended to redesign this version and conduct more research.

Chapter 9: Conclusions and recommendations

Chapter nine about the final conclusions and recommendations for eSignus. The first paragraph is an overall conclusion, and it will answer the main question (9.1). The second and final paragraph will be overall recommendations (9.2).

9.1 Conclusion

To answer the main question, “What is the most effective method to develop the first version of the charger for a production of maximum of 300 units and what is the most effective method to mass produce the final version of the HASHWallet charger?’’ It is important to look at the different production methods that where researched. Selective laser sintering (SLS-printing) would be the most effective method of production for the first version of the charger, that is supposed to be only developed for the founder’s edition of the HASHWallet’s (300 units). Injection moulding would be the best solution for the mass production version of the HASHWallet charger, because this is the most cost-effective solution on a large scale. Also, this guarantees higher quality outcome when done correctly. Compared to additive manufacturing techniques. But injection moulding comes with some important drawbacks, like expensive mould costs and complex design for manufacturing guidelines where the charger design is limited.

9.2 Recommendations

During the final development process of the charger, it became clear that one of the mass production charger part designs has a minor flaw and it is recommended to go for the second designed method, where the USB-C part of the charger is integrated within the top part of the chassis, please see figure 7.1 for more information about this design and please read chapter 8 for more in-depth information. The other pre-designed version of the charger is more durable but having a different top chassis colour will not be possible for this version, also this version will need to be created with the correct draft angles to be fully manufacturable. To ensure a high-quality charger it is upon most importance that the newer designs are checked and validated again with simulation software. This software can help predict if certain designs need to be changed. The first version of the HASHWallet charger is checked and validated correctly and can be produced with the selective laser sintering method. As well for this charger it is important that the production of the founder’s edition charger is well conducted to ensure high quality product. This can be done by producing a few test samples and doing an overall quality control. For the manufacturing of the mass production version of the HASHWallet charger, it is important to contact an external company that is able to design an injection mould and help with the manufacturing process. The design and development of one or multiple injection moulds can get expensive, and for that reason it is only advised to invest in an injection mould when the output of charger is listed as mid or high-volume manufacturing. This means that the output of chargers needs to become greater than 5000> units. For low-volume production (<500 units) it is recommended to use additive manufacturing techniques in combination with the first designed charger.

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Glossary:

Symbol / abbreviation	Variable	Definition
1. FDM	Fused deposition modeling	3D printing technology
2. MSLA	Mono Stereolithography	3D printing technology
3. SLA	Stereolithography	3D printing technology
4. SLS	Selective laser sintering	3D printing technology
5. HASHWallet	Main product eSignus	Wallet where crypto assets can be stored on
6. Hardware wallet	Hardware wallet	Wallet where crypto assets can be stored on
7. Li-ion	Lithium-ion batteries	Battery type
8. USB-C	USB-C Port	Adapter type for charging methods
9. Poka-yoke	poka-yoke	A lean manufacturing process that helps to avoid to mistakes
10. USP	Unique selling point	Defines the unique quadratics from a product or service
11. Polyethylene	PE	Type of plastic material
12. Polypropylene	PP	Type of plastic material
13. Acrylonitrile Butadiene Styrene	ABS	Type of plastic material
14. Polyoxymethylene	POM	Type of plastic material
15. Polystyrene	PS	Type of plastic material
16. DMADOV	DMADOV	Methodology

Attachments

Attachment 1: DMADOV phases:

1. Define phase

1.1 Defining the project goals

The main project goal is to develop two different versions of a charger that can charge the HASHWallet. Both versions of the charger should be similar to reduce product development cost. The HASHWallet was originally designed to only utilise the wirelessly charging method. But because customers would like to have a physical way of charging the hardware wallet, and to add a redundancy (fail-safe) option to still use the HASHWallet after the battery has been slightly damaged or when the battery lifetime has been depleted after many charge cycles.

> "While wireless charging is convenient, we believe that the user may not have access to one or may need much faster charging than an inductive charger can provide. Obviously, this feature will be shipped along with the other components absolutely free of charge for our supporters. (Masaki Hatomi, 2021)"

For both designs there will be made multiple prototypes until the final prototype fully functions and all the requirements are met. These requirements are determined in the measure phase. In the verify phase the final designs will be tested and verified. The designs including the prototypes need to be finished before 12th of January.

Final Deliverables:

- Plan of action (PVA)
- Full DMADOV project approach documentation
- Charger designs in CAD Software (3D)
- Operational protypes (3D Printed versions of both chargers)
- Final Charger for the first batch (Founder edition HASHWallet - 300 units)
- Final Charger designs and manufacturing setup for future versions of the HASHWallet (Second batch 3000-5000 units in 2022)

6.2 Project setup

For this project the DMADOV methodology will be used to guarantee that the project is well defined, measured, analysed, designed, optimised, and verified. See figure 1.1 for the project setup.

7. **Define** (defining the project goals and project setup)
8. **Measure** (Measuring and determining requirements**)**
9. **Analyse** (analysing available information and doing research into manufacturing techniques)
10. **Design** (Design first batch version with prototypes)
11. **Optimise** (Design mass production version with prototypes)
12. **Verify** (verify the final designs and determine efficient production methods

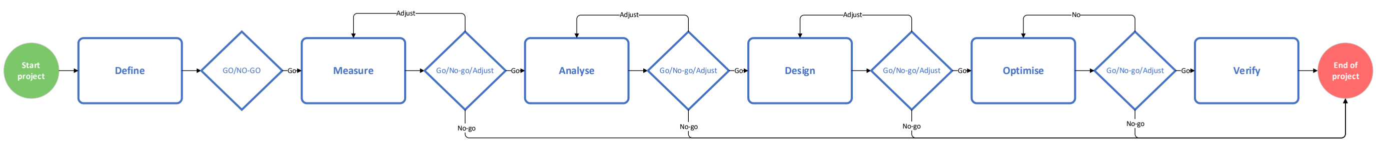


Figure 2.1 DMADOV project approach

1.3 Main-question

How will the first version of the charger be developed for a maximum of 300 units and how will the final version of the charger be optimised for mass production before Q1 2022?

1.4 Sub-questions

Define:

- *What is the project approach and how will the goals be defined?*

Measure:

- What are the risks and how can they be measured?
- What is the schedule that must be met, and what are suitable milestones?
- What requirements do customers and end-users have?

Analyse:

- *What type of production method is best suited for small and large batches?*
- *Which types of materials will be best suited for the mass production of the charger?*
- *How will the charger be durable, repairable, and recyclable?*

Design:

- *Which charger design is best suited for a production size of 300 units?*
- *Will the final specifications and dimensions change before optimising the design?*

Optimise:

- *What type of adjustments must be made before the charger can be mass-produced?*
- *Does the final charger have all requirements set?*

Verify:

- *What type of production method(s) will be best suited to produce both versions of the charger?*

1.5 Project activities

All the activities are noted within table 1.1. In Table 1.2 a RACI Matrix displays who of the team member is responsible, accountable, consulted, and informed at every phase of the project.

Table 1.1 Phases of the project defined

Phase 1: Define	**Phase 2: Measure**	**Phase 3: Analyse**
- Plan of action (PVA) - Cover page - Problem orientation - Research foundation - Project approach and organisation - Defining project goals - Risk assessment	- Supportive models - Project schedule - Survey - Customer requirements	- Set-up up CTQ´s - Kano model - Durability research - Final specifications - Manufacturing techniques - Material options - Checking available information
Phase 4: Design	**Phase 5: Optimise**	**Phase 6: Verify**
- 2D Designs - 3D CAD designs in 3ds Max & Fusion 360 - Feedback on designs - 3D printing first design - Prototype testing	- Optimise and changing design flaws - Final prototype - Checking plan of requirements	- Creating Bill of materials (BOM) - Process flowchart for manufacturing processes - Required production techniques - Final verification of project

1.6 RACI Matrix

All the main activities are noted within table 1.2. The RACI Matrix displays who of the team members are responsible, accountable, consulted, and informed for certain tasks/phases.

Table 1.2 RACI Matrix

Project	Dylan	Sebastián	José	Daniel	External partners
1. Documentation – research paper	*R*	*A*	*C*	*C*	*I*
2. Define	*R*	*A*	*C*	*C*	*I*
3. Measure	*R*	*A*	*C*	*C*	*I*
4. Analyse	*R*	*A*	*C*	*C*	*I*
5. Design	*R*	*A*	*A*	*C*	*I*
Designing the chargers (3D)	*R*	*A*	*C*	*C*	*C*
Prototyping & Testing	*R*	*A*	*C*	*C*	*I*
5. Optimise	*R*	*A*	*A*	*C*	*I*
Final Design Mass production	*R*	*A*	*C*	*C*	*C*
6. Verify	*R*	*A*	*A*	*C*	*I*
internal communication	*R*	*R*	*R*	*R*	*I*
External communication	*A*	*R*	*R*	*R*	*I*
Manufacturing	*C*	*C*	*R*	*C*	*C*

Table	
Responsible	*R*
Accountable	*A*
Consulted	*C*
Informed	*I*

1.7 General project planning:

The project has been separated in sprints of two weeks. In every sprint there will be multiple tasks divided between the project group. In total there are six sprints planned that start from 24th of September to 22nd of December. After this the main assignment should be completed. After this there is still time to hand in the project documentations.

Sprints, WBS and planning

Sprint 0 @September 24, 2021 → September 27, 2021

- [x] ~~Final design concept @September 9, 2021~~
- [x] ~~3D prototyping @September 15, 2021~~
- [x] ~~3D impression @September 17, 2021~~
- [x] ~~First prototype test @September 20, 2021~~
- [x] ~~Circuit board testing @September 24, 2021~~
- Defining the project 1
  - Plan of action (PVA)
    - [x] ~~Problem orientation~~
    - [x] ~~Project exploration~~
    - [x] ~~Defining the research~~
    - [x] ~~WBS planning~~
    - [x] ~~First risk analysis (intern & extern)~~
    - [x] ~~RACI Matrix~~
    - [x] ~~Cost estimations~~
  - Program of requirements
    - [x] ~~Main project requirements~~
    - [x] ~~Functional requirements~~
    - [x] ~~Operational requirements~~

Sprint 1 @September 27, 2021 → Friday

- [x] ~~Meeting about project/sprint start @September 27, 2021~~
- [x] ~~Making changes to first design/prototype (**office version/test unit**) @September 27, 2021 → Last Tuesday~~ 1
- [x] ~~3D printing a second prototype (**office version/test unit**) @Last Tuesday → Last Wednesday~~
- [x] ~~Testing the second prototype (**office version/test unit**) @Last Wednesday → Last Friday~~
- [ ] Changing design to improve durability @Tomorrow → Friday
- [ ] Meeting about the progress of the project (**go/no go moment**) @Friday
- [ ] Setting up the SLA 3D printer @Thursday → Friday
- Measuring phase @September 27, 2021 → Last Friday
  - [x] ~~Project schedule~~
  - [x] ~~Setting up an survey~~
  - [x] ~~Sending the survey~~
  - [ ] Critical to quality (CTQ´s)
  - [ ] Business case
- Analysis phase @Yesterday → Friday
  - [ ] Supportive models (Kano, function tree)
  - [ ] Durability research
  - [ ] Material research
  - [ ] Review risk assessment

Sprint 2 @Next Monday → October 22, 2021

- [ ] Meeting about project/sprint start @Next Monday
- [ ] Meeting about the progress of the project (**go/no go moment**) @October 22, 2021
- Design phase
  - [ ] AutoCAD drawings (founders edition charger - **first version**)
  - [ ] First 3D/2D designs (founders edition charger - **first version**)
  - [ ] Final designs (founders edition charger - **first version**)
  - [ ] 3D printing prototype (founders edition charger - **first version**)
  - [ ] Prototype testing (founders edition charger - **first version**)

Sprint 3 @October 25, 2021 → November 5, 2021

- [ ] Meeting about project/sprint start @October 25, 2021
- [ ] Meeting about the progress of the project (**go/no go moment**) @November 5, 2021
- Optimization (**redesign**) phase
  - [ ] Designing mass production version of the charger
  - [ ] First prototype
  - [ ] Redesign when necessary
  - [ ] Checking final design on requirements

Sprint 4 @November 8, 2021 → November 19, 2021

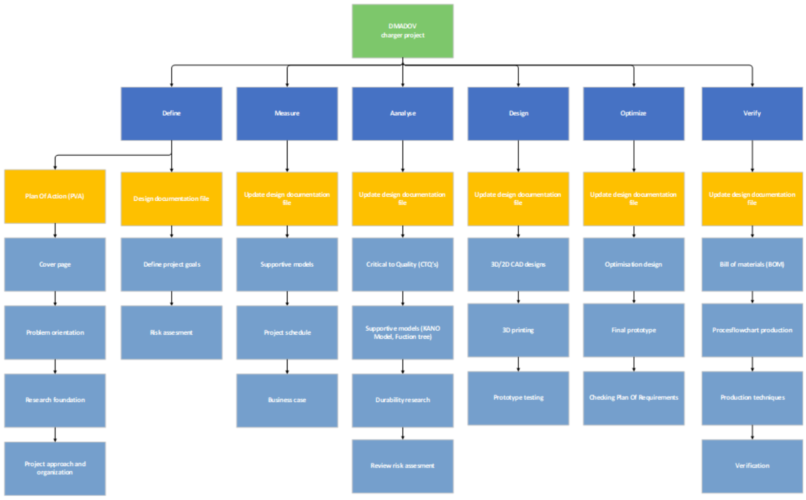
- [ ] Meeting about project/sprint start @November 8, 2021
- [ ] Meeting about the progress of the project (**go/no go moment**) @November 19, 2021
- Optimization (**redesign**) phase
  - [ ] Redesign when necessary
  - [ ] second prototype
  - [ ] Checking final design on requirements

Sprint 5 @November 22, 2021 → December 3, 2021

- [ ] Meeting about project/sprint start @November 22, 2021
- [ ] Meeting about the progress of the project (**go/no go moment**) @December 3, 2021
- Verification phase
  - [ ] Setting up Bill of materials (BOM)
  - [ ] Creating flowchart for production steps
  - [ ] Optimal production techniques
  - [ ] Verification of the charger

Sprint 6 @December 6, 2021 → December 17, 2021

- [ ] Meeting about project/sprint start @December 6, 2021
- [ ] Final meeting (**go/no go moment**) @December 17, 2021
- [ ] Writing DMADOV chapters @December 6, 2021 → December 17, 2021
- [ ] Finishing project documentation @December 6, 2021 → December 17, 2021



2. Measure phase

2.1 Risk analysis

See reference plan of approach (PVA), chapter: 3.4.1 and 3.4.2

2.2 Survey for quantifying the research

Within the DMADOV Methodology it is important to require data to determine the critical to qualities (CTQ´s) for the product development. The data was collected by sending a survey out to different type of users (see figure 2.1). These users have different backgrounds and ages. The data sample is relatively small (n=21) compared to the number of users using chargers. This makes data sample not sufficient for a complete quantitative research paper, but the survey helped to receive some interesting information about different customer expectations. This information will be used for the development of the charger.

The form can be visited by clicking this link.

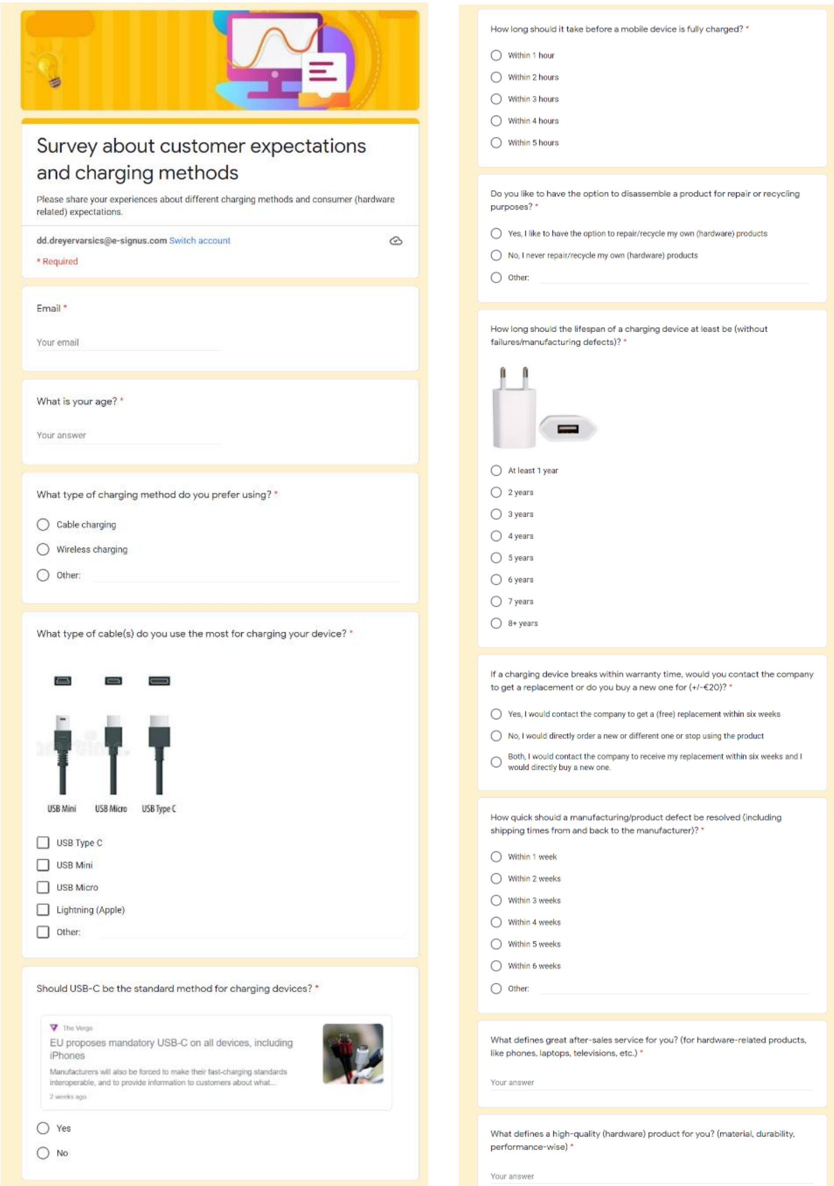

Survey about customer expectations and charging methods
Please share your experiences about different charging methods and consumer (hardware related) expectations.
dd.dreyervarsics@e-signus.com Switch account
* Required
Email *
Your email
What is your age? *
Your answer
What type of charging method do you prefer using? *
Cable charging
Wireless charging
Other:
What type of cable(s) do you use the most for charging your device? *
USB Mini
USB Micro
USB Type C
USB Type C
USB Mini
USB Micro
Lightning (Apple)
Other:
Should USB-C be the standard method for charging devices? *
The Verge
EU proposes mandatory USB-C on all devices, including iPhones
Manufacturers will also be forced to make their fast-charging standards interoperable, and to provide information to customers about what...
2 weeks ago
Yes
No
How long should it take before a mobile device is fully charged? *
Within 1 hour
Within 2 hours
Within 3 hours
Within 4 hours
Within 5 hours
Do you like to have the option to disassemble a product for repair or recycling purposes? *
Yes, I like to have the option to repair/recycle my own (hardware) products
No, I never repair/recycle my own (hardware) products
Other:
How long should the lifespan of a charging device at least be (without failures/manufacturing defects)? *
At least 1 year
2 years
3 years
4 years
5 years
6 years
7 years
8+ years
If a charging device breaks within warranty time, would you contact the company to get a replacement or do you buy a new one for (+/-€20)? *
Yes, I would contact the company to get a (free) replacement within six weeks
No, I would directly order a new or different one or stop using the product
Both, I would contact the company to receive my replacement within six weeks and I would directly buy a new one.
How quick should a manufacturing/product defect be resolved (including shipping times from and back to the manufacturer)? *
Within 1 week
Within 2 weeks
Within 3 weeks
Within 4 weeks
Within 5 weeks
Within 6 weeks
Other:
What defines great after-sales service for you? (for hardware-related products, like phones, laptops, televisions, etc.) *
Your answer
What defines a high-quality (hardware) product for you? (material, durability, performance-wise) *
Your answer

Figure 2.1 Survey about customer expectations and charging methods

The data that was collected from the surveys is listed below.

1. **Average age that filled in the survey** = 29 years old (n=21)

The ages ranged between 18 and 64 years old with an average of 29.

2. **What type of charging method do you prefer using?**

80 precent of the people that filled in the survey prefer using a cable charging method over wireless charging (see figure 2.2). Therefor it is recommended that the HASHWallet also needs a way to be charged with a wire. The HASHWallet already includes an option to charge the hardware wallet wirelessly.

3. **Should USB-C be the standard method for charging devices (figure 2.3)?**

100 precent of the people that filled in this survey have said that USB-C charging should be the main standard. At the moment the European government is already trying to reduce electronic waste by forcing USB-C as a standard charging method for electronic devices (Cristina Criddle, 2021).

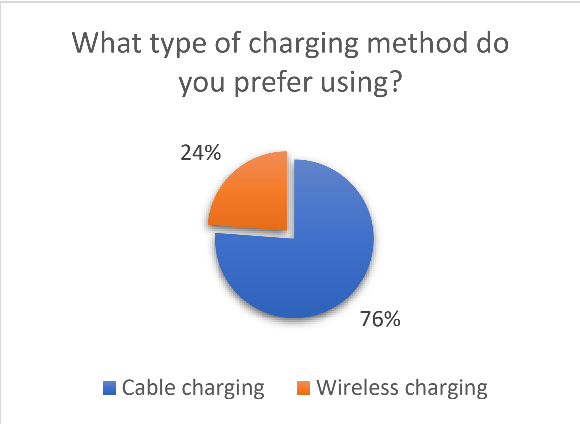


Figure 2.2 Preferred charging method

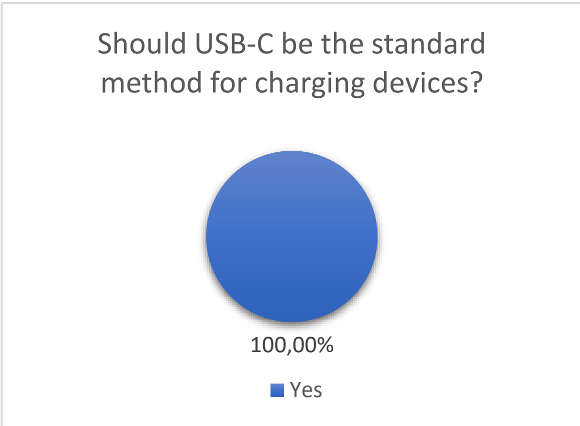


Figure 2.3 Should USB-C be the standard?

4. **How long should it take before a mobile device is fully charged? =** 1.73 hours (n=20)

With this data we can set a standard minimum on how long it should take to charge the HASHWallet with the dedicated charger.

5. **Do you like to have the option to disassemble a product for repair or recycling purposes?**

10 out of the 20 people that filled in the survey never repairs or recycles their own hardware related products (figure 2.4). Therefor it is important that there will be more research concluded about how the charging device will be constructed with repairability and recyclability in mind.

6. **How long should the lifespan of a charging device at least be (without failures/manufacturing defects)?** = 4.9 years (n=21)

With this data we collected from the survey about the expected lifespan of a charging device, it is possible to set a standard minimum on how long the device will last without failures.

7. **How quick should a manufacturing/product defect be resolved (including shipping times from and back to the manufacturer)?** = 2,1 weeks (n=21)

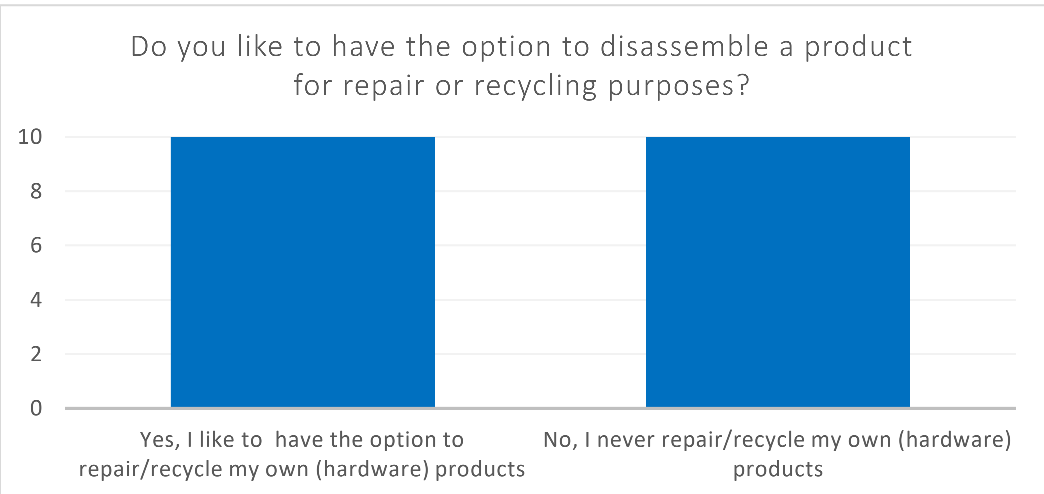


Figure 2.4 option to disassemble a product.

8. **If a charging device breaks within warranty time, would you contact the company to get a replacement or do you buy a new one for (+/-€20)?**
   43 precent of the survey answers say that they would contact the store or supplier where they bought their product to receive a replacement. 38 precent of the people will not contact the product the shop or supplier when a cheaper product fails within warranty time and 19 precent will both seek contact and directly buy a new one.

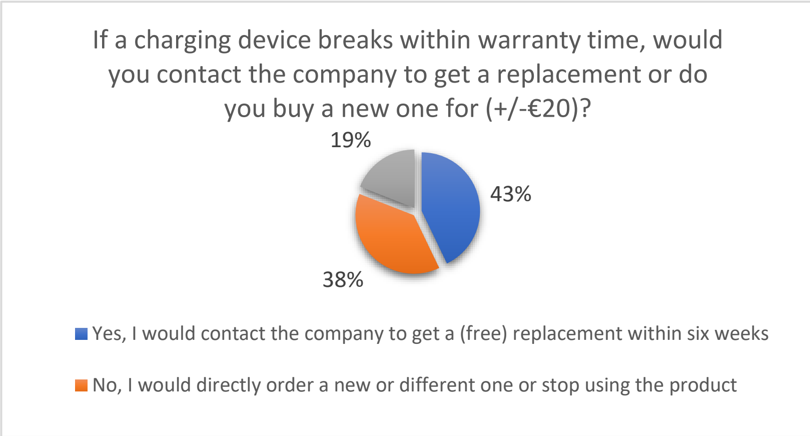


Figure 3.5 Replacement

9. **What defines great after-sales service for you? (for hardware-related products, like phones, laptops, televisions, etc.)**
   The most important answers that were collected from the survey are listed below.
   - To keep the customer updated about new features or products
   - Fast customer support with good solutions to any possible problems
   - Fast response, direct replacements, preferably free of charge and shipping. It makes customers more likely to stick to that specific brand or supplier
   - The company should always at least try to help the customers. Even when there isn't much to do.
   - If the customer service replies fast and offers a few solutions that are fair.
   - Fast help, and keep in touch about the progress
   - Being able to get the product repaired/ a new one within warranty
   - A helpful, reliable, and quick customer service. If I receive a malfunctioning device, I'd expect a free replacement asap or a quick refund. Having service support held by people with the required expertise.
   - An informal follow up mail to thank me for my purchase and a quick and nice customer service. I once received an e-mail with a GIF/meme and that convinced me to keep their product instead of the alternative I bought to compare in real-life
   - Fast contact by phone or mail. Easy service
   - If its broken you can choose if you want a new one or not. Or they send a new one

10. **What defines a high-quality (hardware) product for you? (material, durability, performance-wise)**
   The most important answers that were collected from the survey are listed below.
   - A product that doesn't have any defects in the warranty period with normal use.
   - If the products works the way the producer sells it
   - Nice materials, no offsets like panel gaps in cars that should be even all around, sleek design, smooth to use, easy to understand
   - Something that has a long lifespan, is sustainable, looks good, made out of a good material
   - When the product is build durable and that the device has a long life span. I also like if performance is great, but it should not damage or decrease the product lifespan by much.
   - Great finishing (I have no material preferred). Minimum 2 years durability. I do not want to worry about the performance, anybody can use the product without reading manuals.
   - A high quality product must be robust, durable and show no performance shortcomings. It should be simple to use and with consistent feedback. Its operation must be transparent (as far as possible), indicating to the user what is happening at any given moment. Apart from any additional features, it must fulfil its main function correctly and efficiently.
   - The product must accomplish all features expected and to stay working at least several years more.
   - I do everything with my phone so performance wise and durability is a number one thing.

2.3 Critical to qualities (CTQ´s)

The voice of the customer and critical to qualities have been mapped with the help of the collected data from the survey (see table 2.1). The Critical to qualities (CTQ´s) are visually presented in figure 2.6.

Table 2.2 Voice of customer for CTQ flow-down

Customer needs	Expectations
Quality	- The customer expects a well-polished product that has a life span of at least 4.9 years. - Accomplish all expected features from customers - Performance should not decrease product lifespan
Durability	- The product should be built durably, so it can handle everyday use.
Customer needs	- The charger needs to have a USB-C port
Expectations	- 50 precent of the customers expect that the device is repairable and recyclable. - Devices should be repaired within two weeks - Great after sales service - A well-polished product
Preferences	- 76 precent of customers prefer using cable charging over wireless charging.
After sales (service)	- Quick solutions/responses when the product does not function well - Helpful and reliable after service - Multiple contact methods (e-mail, phone and/or chat)

CTQ Tree:

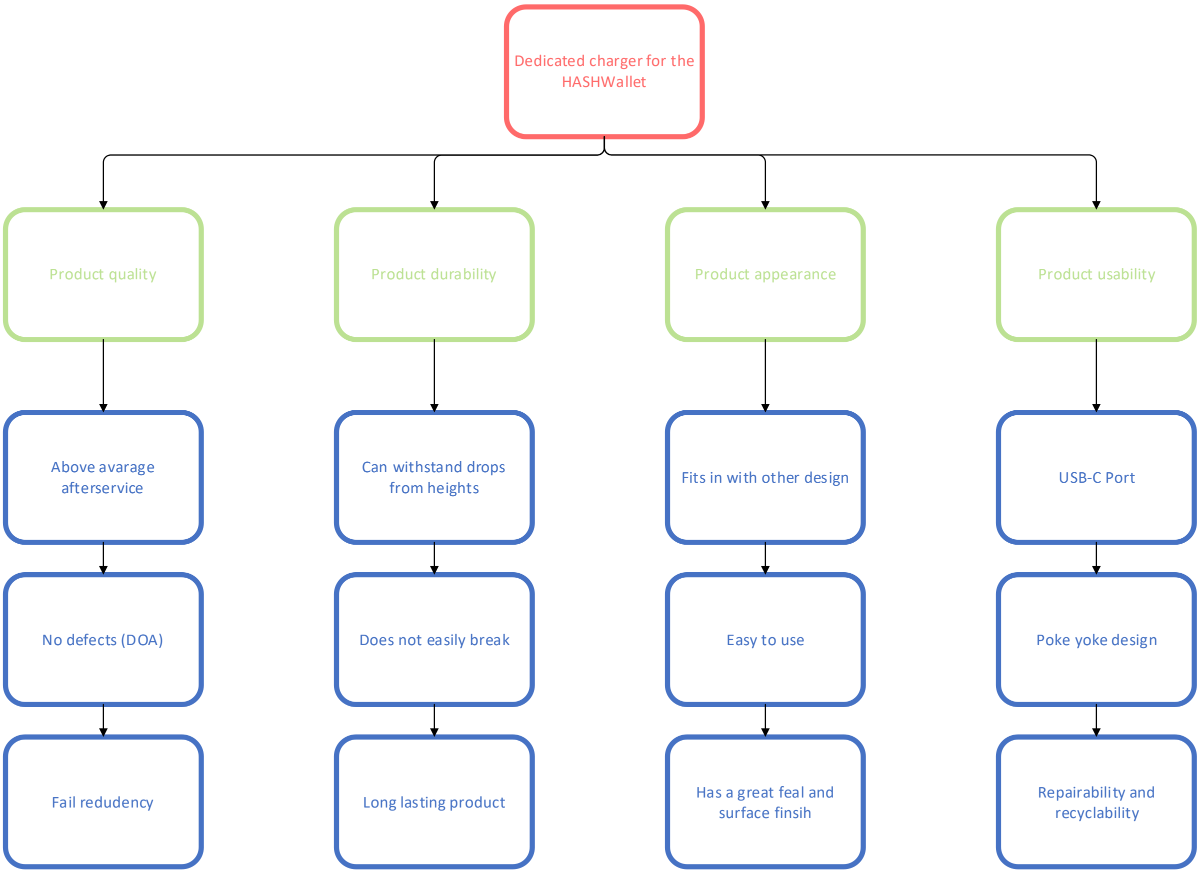


Figure 2.6 CTQ Tree

2.4 estimated charger and project costs

See table 2.3 for the estimated project and charger cost. These costs are based on averages and the data is collected from multiple internal sources. The external sources are mainly based from form labs (Formlabs, n.d.)

Table 2.3 Cost estimates of the first version of the charger

Estimate costs first version (300 units):	**Estimate costs: in €**
Total internal wages for employees	€2500
Aurelio´s laboratorial expenses (R&D)	€2500
Material expenses	
- Contacts (300 units)	€ 186
- USB-C connectors (300 units)	€ 225
Manufacturing expenses	
- 3D printer with accessories (residual value: €200)	€350
- Lab pick and place system	€2000
- 300 printed circuit boards	€450
- **Plastic case production (300 units)**	
- Chassis production with SLS printer and painting (300*€3)	€ 900
- Final mounting boards to case (30 seconds*300/60=150 min) (€35 uur)	€87.50
- Gluing top to bottom part charger (60 seconds*300/60=300 min) (€35 uur(	€175
Transport costs	€500
Total project cost for the first version	**€ 9.873**
Total cost per unit before depreciation	**€ 32,91**
Total project cost - depreciation	**€ 9.361**
Total cost per unit before depreciation	**€ 32,25**

Estimate costs second version (3000 units):	**Estimate costs: in €**
Total internal wages for employees	€2500
Material expenses	
- Contacts (3000 units)	€ 186
- USB-C connectors (3000 units)	€ 225
Manufacturing expenses	
- Injection Mould total expenses (3x€1500)	€4500
- Lab pick and place system	€2000
- 300 printed circuit boards	€800
- **Plastic case production material (3000 units)**	€ 600
- Electricity, labor and, materials for case production	€ 3000
- Final mounting boards to case (30 seconds*300/60=1500 min)	€ 500-750
Total cost project for the second (mass production) version	**€ 14.436**
Cost per unit	**€ 4,81**

3. Analyse phase

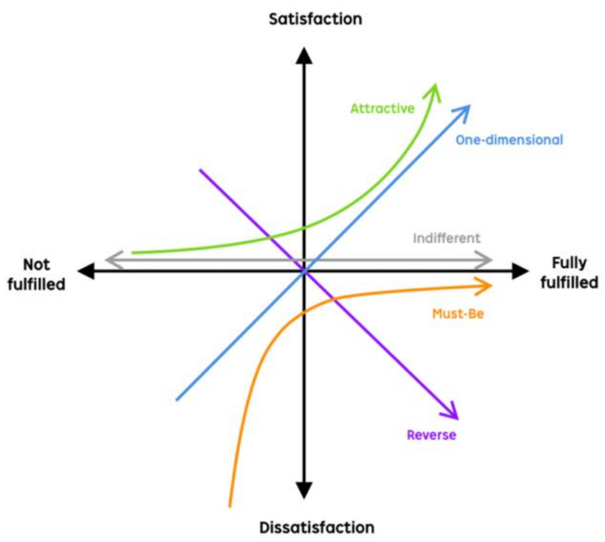
3.1 Customer expectations

Kano model

By using a Kano model, you can map all the expectations that are likely to satisfy customers. There are three different type of features. The basic features that the charging device must have. Performance based features and attractive features. The most important features are the basic ones. Almost all end-users expect these. The performance features are great to have, and consumers would be more satisfied with their product. This is the same as for attractive features, they are great to have but do not add much to the core values.

Table 3.1 Kano model charger for the HASHWallet

Nr.	Customer expectations
1	The product is durable
2	The product has no defects
3	The product is user friendly
4	The product functions optimal
5	The product is designed with a fail-safe redundancy
6	The product is designed with poka-yoke in mind
7	The product is as cheap as possible
8	The product is safe to use
9	The product can be dissembled for repair/recycling
10	The product is compact
11	The HASHWallet can be used while charging
12	The product fits in the HASHWallet packaging
13	The LED lights of the HASHWallet are visible while in use
14	The product works with different versions of the HASHWallet or other Hardware wallets that eSignus makes
15	The product should charge the HASHWallet faster than with the wireless method
16	The product should have a USB-C port
17	The material used has a great finish.



Basic (must-be) features
1, 2, 4, 5, 8, 11, 13, 16
Performance features (one dimensional)
3, 6, 7, 10, 14, 15
Attractive features
9, 12, 17

3.2 Customer requirements

These requirements have been setup after completing and analysing the measure phase. The requirements have been divided in performance, appearance, ergonomics, mechanical properties, manufacturability, Usability, availability, norms/standards, costs, and durability. These requirements (see table 3.2) will be used for the validation process of the charger.

Table 3.2 Customer requirements

	Nr.	Customer requirements
		Performance
✓	1	The product functions optimally
✓	2	The product charges the HASHWallet
✓	3	The product must faster charge than a wireless charger
		Appearance
✓	1	The product is precisely finished without loose parts
✓	2	The material used has a great feeling/finish
✓	3	The design must resemble a charger
✓	4	The design must fit with the HASHWallet design
		Ergonomics
✓	1	The product is easy to use
✓	2	The product is safe to use
✓	3	The HASHWallet cannot put in wrongly (Poka-Yoke)
		Mechanical properties
✓	1	The product must be durable
		Manufacturability
✓	1	The first version must be produced in a small batch
✓	2	The second version needs to be able to be produced in medium to large batches.
✓	3	The product needs to be easy to manufacture
		Usability and environment
✓	1	The product must be able to withstand external temperature changes between 0-40 degrees Celsius.
✓	2	The product must withstand different voltage currents.

	Nr.	Customer requirements
		Availability
✓	1	The product must be delivered with the founders edition HASHWallet
✓	2	There needs to be after sale service available for the product
✓	3	The product must be deliverable in countries where the HASHWallet is also available.
		Norms and standards
✓	1	The product must last for at least two years with included warranty.
✓	2	The product must be sufficiently tested and have a CE marking.
✓	3	The product must comply with international legislations.
		Costs
✓	1	The product needs to be manufactured as affordable as possible, without losing quality standards.
✓	2	The second version of the charger needs to be cheaper to manufacture than the first version of the charger.
		Durability
✓	1	The product should on average at least last for 5 years without any manufacturing products
✓	2	The product must withstand drops from 1,5-meter heights.
✓	3	The charger must withstand friction from the hardware wallet.
✓	4	The product must not damage the hardware wallet.

3.3 First version of the circuit board

The first version of the circuit board is displayed in In figure 3.1. This board was an early version that was used to charge and start the HASHWallet. The design needed to change, because the footprint was too large to fit in a portable charger. That is why the laboratory where eSignus cooperates with designed a new version of this board (see figure 3.2 and 3.3).

Figure 3.1 First circuit board

3.4 Second version(s) of the circuit board

The second version of the circuit board has changed a lot from the first version. This was required because it needed to be compact enough to fit in a charger. For this version of the circuit board there are made two different versions. The first version (figure 3.2) is the easiest and cheapest one to produce, this version has the USB-C connecter on the top. The disadvantage of this version is that the USB-C port sits a little higher, so it is less compact. Also, the USB-C port has less resistance to the insert of a plug. The second version is more expensive to produce (figure 3.3). This version is about one mm less height on the USB-C part, but the connector thickness is still higher, so it is not recommended to use this part for the production or design of the charger.

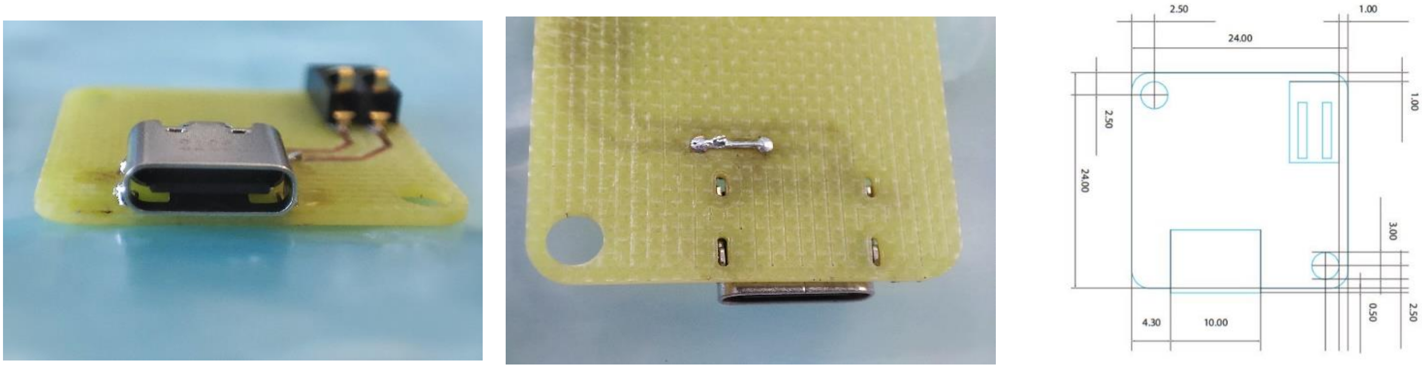


Figure 3.2 Circuit board with USB-C port attached on top

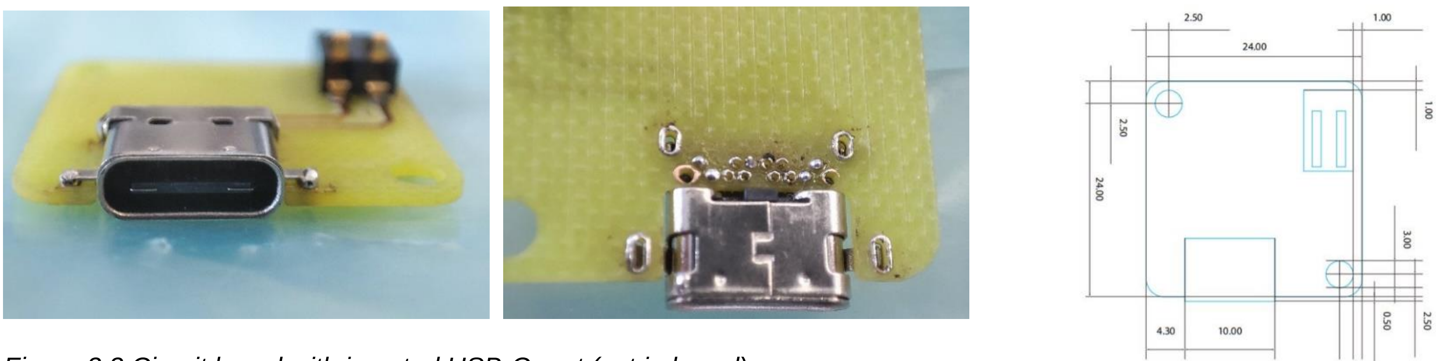


Figure 3.3 Circuit board with inserted USB-C port (cut in board)

3.5 Concept drawings of the charger

For the first concept drawings there were some requirements where the charger should abide by. It was important that while charging the HASHWallet that the operational LED-lights are visible. These lights are required to operate the device. Besides that, the charger must have visual elements, so the user directly knows how the card is plugged in correctly (see figure 3.4).

Figure 3.4 Two different concept drawings of the charger

3.6 Final concept drawings of the charger

For the final concept the project team has chosen the design from figure 3.5, because it suits the design of the HASHWallet and the brand well, the screen is not covered, it has all the visual elements that are required, and the charger grips the hardware wallet enough for a tight fit.

Figure 3.5 Final concept drawing of the charger

Placement circuit board:

The circuit board will be housed in the bottom part of the charger. Because the charging points of the hardware wallet are placed on the bottom part of the HASHWallet (figure 3.6). The circuit board has a dimension of 24*24*1mm and has two holes, a USB type C, and a charging connector build on the plate.

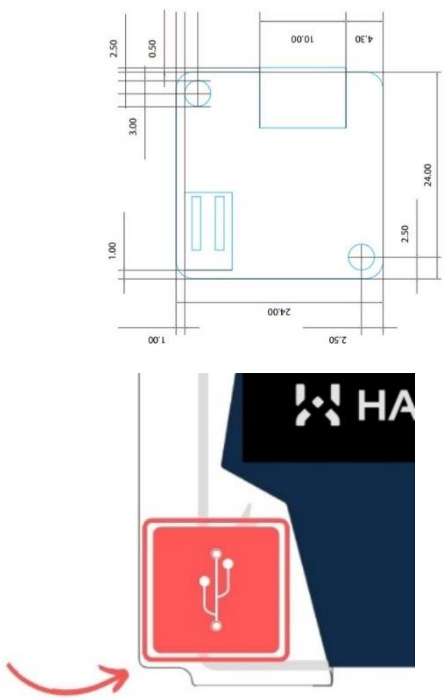


Figure 3.6 Circuit board placement

3.7 Dimensions of the HASHWallet

The dimensions of the HASHWallet are (L*W*H) 85.6*54.03*2 mm but for future versions the thickness of the hardware will decrease from 2 to 1.8 mm. For the exact coordinates and further specifications see figure 3.7.

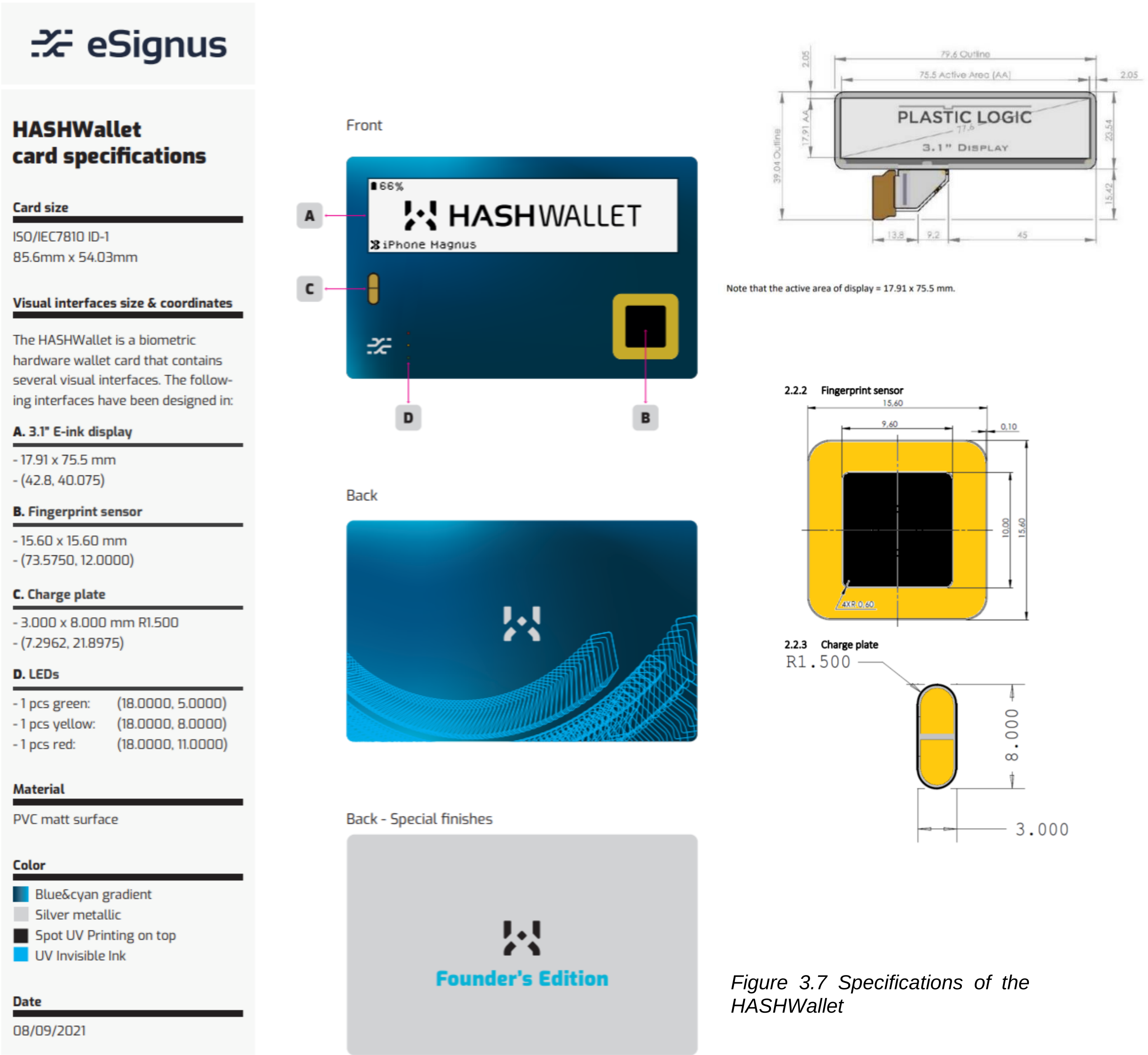
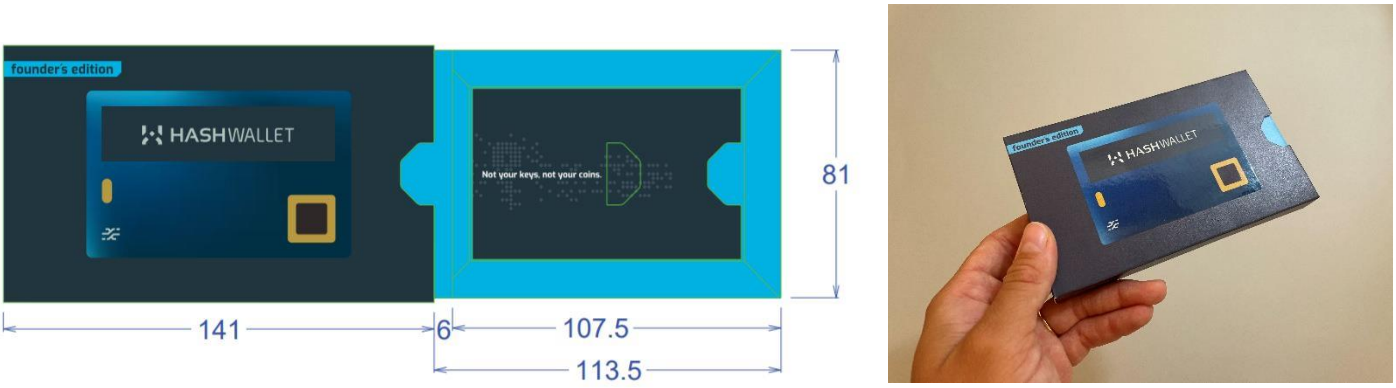


Figure 3.7 Specifications of the HASHWallet

3.8 Dimensions of the packaging

One of the requirements of the project was that the charger should fit in the box design that was already designed. So, the maximum size that the charger can have is (L*W*H) 85*54*15mm. The packaging for the HASHWallet can still be adjusted a bit, but the dimensions should not be larger than the requirements. The dimensions are based on the internal sides for the card slot. The charger will be housed in the bottom part of the packaging, below the HASHWallet.



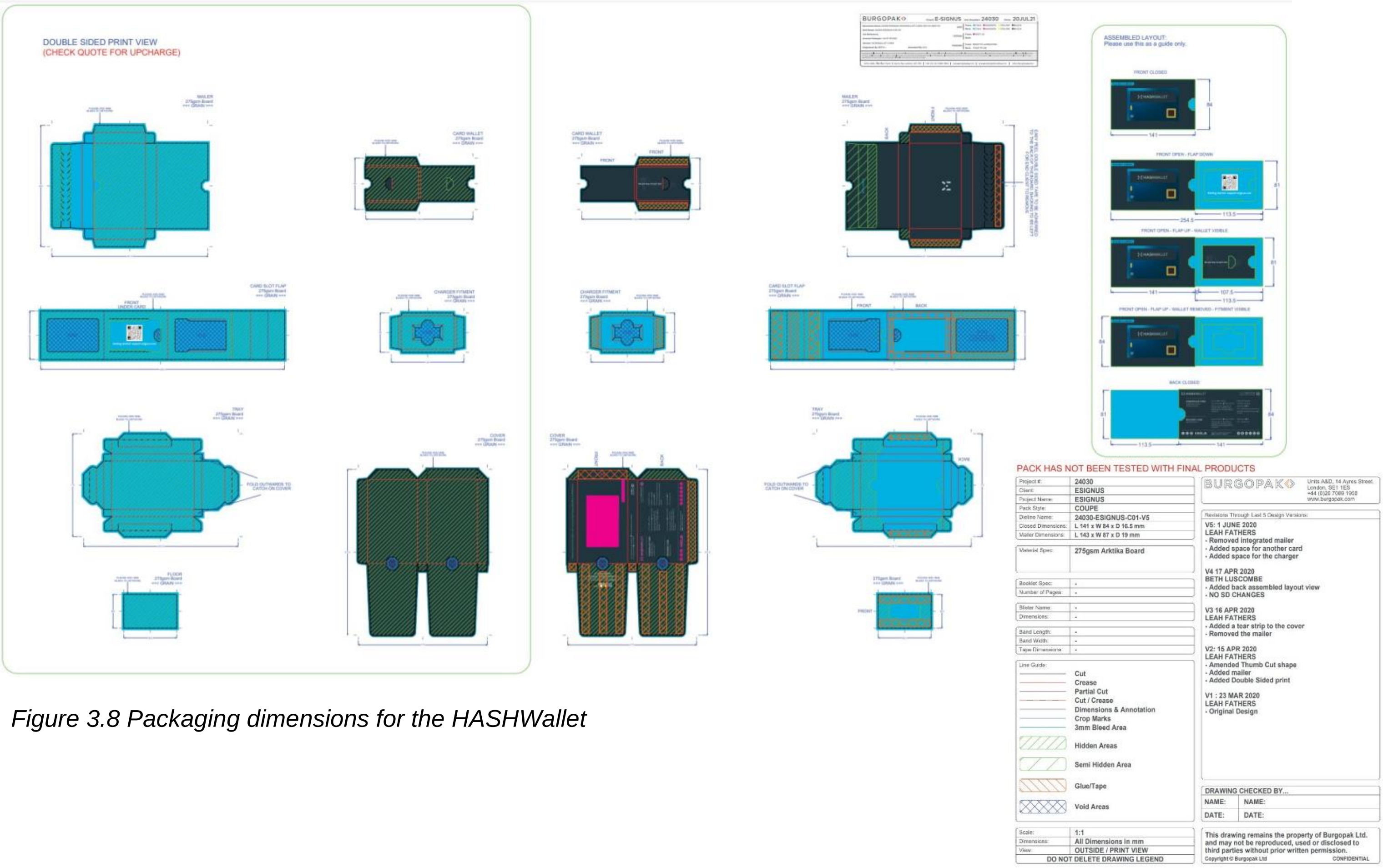


Figure 3.8 Packaging dimensions for the HASHWallet

3.9 3D software tools

For the design of the charger there will be used multiple 3D tools to design, visualize and prototype the charger. The 3D tools used will be Autodesk 3ds max, Fusion 360 and Cura for 3D printing the prototypes. For sharing the files .FBX, .STL and .OBJ files will be the main standard.

3ds Max:

Autodesk 3ds Max will be used for designing the first prototypes and for creating the 3D visualisations. After that the designs will be created within Autodesk fusion 360.

AUTODESK® 3DS MAX®

Figure 3.9 3ds max logo

> 3ds Max is a computer graphics program for creating 3D models, animations, and digital images. It's one of the most popular programs in the computer graphics industry and is well known for having a robust toolset for 3D artists. As one of the most widely used 3D packages in the world, 3ds Max is an integral part of many professional studios and makes up a significant portion of their production pipeline (Autodesk, n.d.).

Material editing within 3ds max:

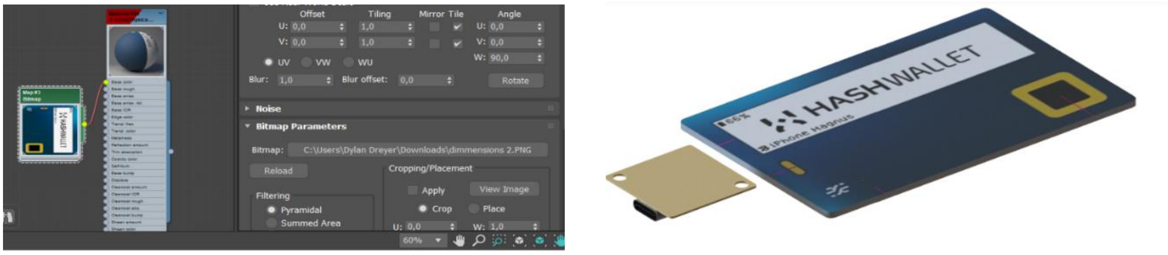


Figure 3.10 3ds max material editor

Fusion 360

Fusion 360 will be used for creating the final 3D designs, the software made for creating accurate manufacturing products.

AUTODESK® FUSION 360™

Figure 3.11 Fusion 360 logo

> Fusion 360 is a cloud-based 3D modelling, CAD, CAM, CAE, and PCB software platform for product design and manufacturing (Autodesk, z.d.).

- Design and engineer products to ensure aesthetics, form, fit, and function.
- Reduce the impact of design, engineering, and PCB changes and ensure manufacturability with simulation and generative design tools.
- Directly edit existing features or model fixtures with the only truly integrated CAD + CAM software tool.

Cura, Chitubox slicer software

Cura and Chitubox will be used as a slicing software tools to 3D print the prototypes. With the help of slicer software's, a 3D printer knows how to print a 3D model by fallowing the paths or adjusting the LCD screen to cure resin.

cura. chitubox®

Figure 3.12 Cura/chitubox logo

> Trusted by millions of users, Ultimaker Cura is the world's most popular 3D printing software. Prepare prints with a few clicks, integrate with CAD software for an easier workflow, or dive into custom settings for in-depth control. At the heart of Ultimaker Cura is its powerful, open-source slicing engine, built through years of expert in-house development and user contributions (Ultimaker, n.d.).
>
> A powerful and easy way to prepare for SLA/DLP/LCD 3D printing. CHITUBOX Basic, a full-featured 3D printing preparation tool, is designed to edit and slice your models with only a few mouse clicks (Chitubox, n.d.).

3.10 Additive manufacturing methods unutilized for prototyping and first batch

FDM 3D printer:

For the first prototype units there will be used a FDM 3D printer (see figure 3.13). These 3D printers print on a heated build plate. The coil will turn due the driving motor that brings in the filament to the extruder. The extruder is around 200 degrees Celsius, after the filament runs through the extruder the filament will melt and creates a layer on the plate. This kind of 3D printing is also the most used method (Grames, 2020).

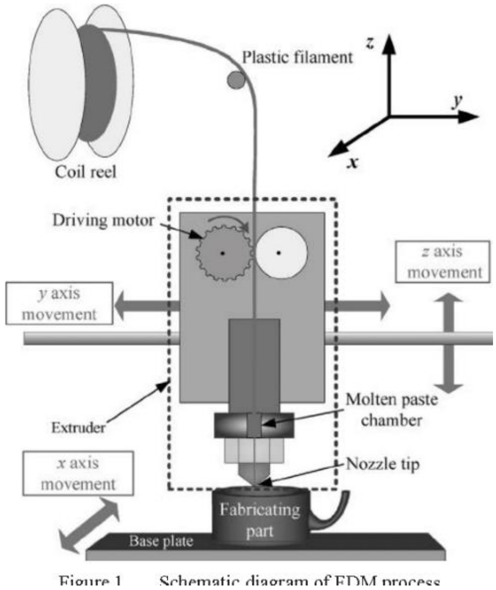


Figure 3.13 FDM 3D Printers

(Mono) stereolithography (M)SLA 3D printer:

For the second type of prototypes, eSignus will use a (M)SLA 3d printer (see figure 3.14). These type of 3D printers print faster and in a higher resolution. But the disadvantage are the smaller build volume, more clean-up work, and the more expensive material it uses to print parts. Instead of using different types of filament spools, SLA printers use different types of resins (Formlabs, n.d.).

Figure 3.14 (M)SLA 3D printer

Selective laser sintering (SLS) 3D printing

For the first 300 charger units the SLS 3D printing method will be utilized (see figure 3.15). The advantages of SLS printing are that the build volume can easily be increased by using larger machines. This step will be outsourced to a local company located in Las Palmas de Gran Canaria. The disadvantages are that there are limited materials to choose from. SLS machines can work with a few polymers, such as nylon and polystyrene. The machine can also handle metals like steel and titanium (Formlabs, n.d.)

For more information about these additive manufacturing techniques see (see figure 3.16)

Figure 3.15 SLS Printer

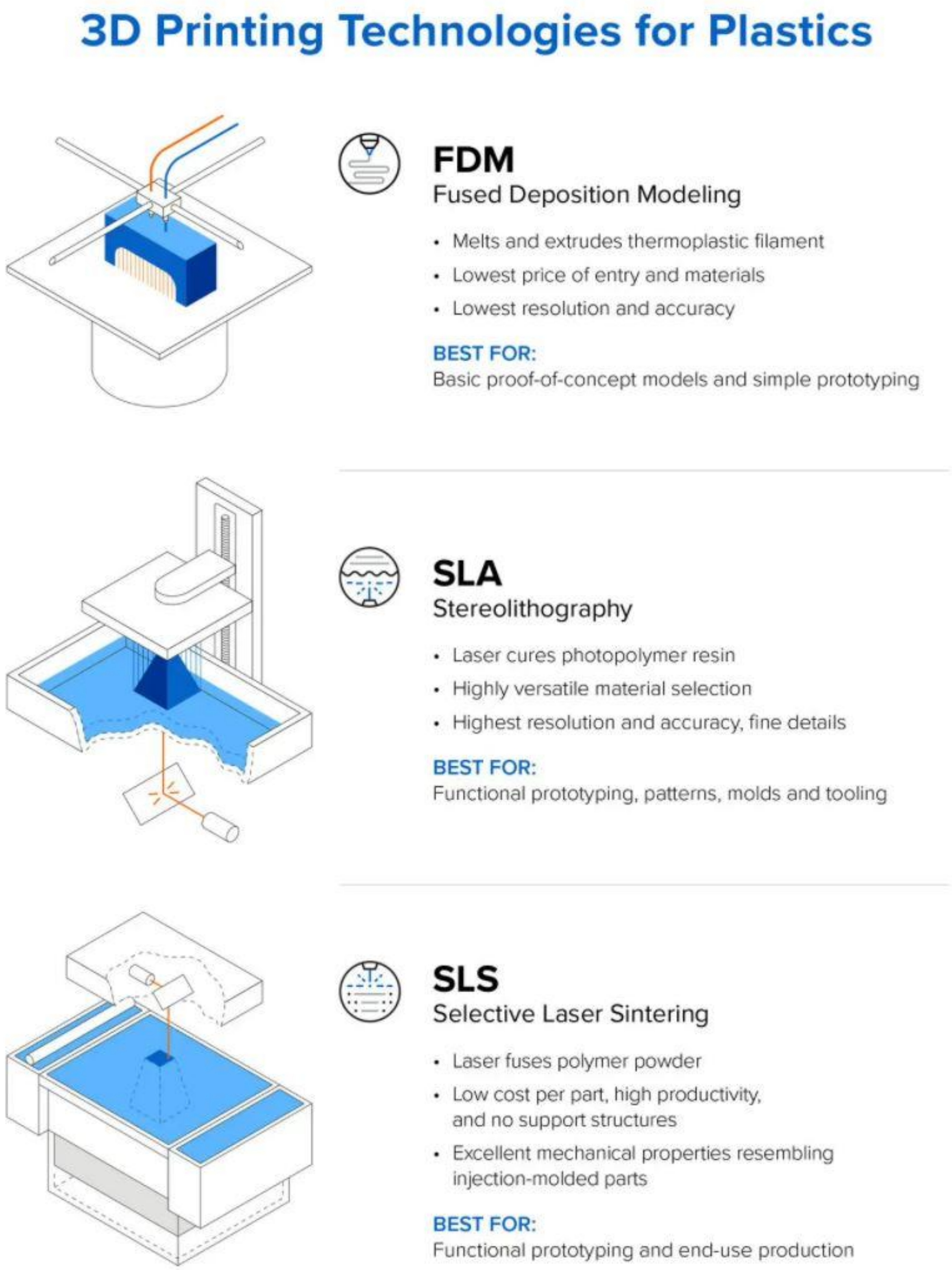


Figure 3.16 Printing methods (Formlabs, n.d.)

3.11 Manufacturing (research)

The main method for producing the mass production version of the charger will be utilizing the injection moulding manufacturing technique. For the first batch it is recommended to get started with a smaller and more affordable injection moulding system that can be used by hand or the SLS additive manufacturing method. For the first version only 300 units need to be produced. Designing and producing an expensive mould will not be feasible for the first batch of 300 units. If injection moulding is a requirement, then its recommended to use a smaller machine like the LNS Model 150A or a desktop injection moulding machine. These machines can be used with an inexpensive resin mould. These moulds are easier and cheaper to produce and can handle up to a few hundred injection shots. Silicone moulds can even be printed with an SLA 3D printer, but it requires flexible resin (+-/€60) that is slightly more expensive to normal resin (+/-€25), that is used for the protypes. Please read chapter 3.11 for more in-depth information about material options.

Figure 3.17 Small injection moulding machine

Designing (resin) moulds (Design for manufacturing):

To guarantee a high-quality product for the end consumer it is important the product has a great finish and is built with durability in mind. For this reason, it is not possible to use only a FDM 3D printer to create the final product. Besides the higher material cost and printing defects it does not fulfil the high-quality standards that eSignus would like to have. Therefor there needs to be created a high-quality mould for the charger or the first units need to printed with an SLS machine. For the first batch there are three production options. The first option is designing and 3D printing an own resin mould that can be used with an affordable injection moulding machine, like the 150A from LNS Technologies (see figure 3.17). The second option would be that a different company that is specialised in injection moulding does the whole moulding and manufacturing part for the first batch 300units, this will probably not be feasible on such small scale. The last option is to manufacture the products with an SLS machine.

> Using 3D printed molds for low-volume injection molding can reduce costs, shorten lead times, and help bring better products to market. In this guide, we will walk you through the steps of using 3D printed molds on your injection molding machine. (Formlabs, n.d.)
>
> **1. Mold Design**
>
> Design the mold for your part in the CAD software of your choice. Adhere to common design rules for additive manufacturing and injection mold design. Design recommendations specific to polymer 3D printed molds can be found in our whitepaper. Upload your design into PreForm, Formlabs print preparation software. Prepare your print and send it to your Formlabs 3D printer.
>
> **2. Mold 3D Printing**
>
> Mold 3D Printing Choose a 3D printing material and begin your print. Rigid 10K Resin at 50 micron layer height is an ideal choice for most mold designs as it combines high strength, stiffness, and thermal resistance.
>
> When possible, it is advised to print the mold flat, directly on the build platform without any supports, in order to reduce warpage. After washing and post-curing, your 3D printed mold is ready to be integrated into your injection molding process.
>
> **3. Mold Assembly**
>
> Prior to assembly, you may choose to finish the mold to meet critical dimensions with hand-sanding, desktop or CNC machining.
>
> It is recommended to place the printed mold inside a standard metal frame, or a Master Unit Die, to support against high pressures and extend the lifetime of your printed mold. Carefully assemble the 3D printed mold inside the metal frame. Add ejector pins, inserts, side-action parts and other components as needed. Install the assembled mold in your injection molding machine.

4. Mold Clamping

Insert the plastic pellets, input the required settings, and begin production. A lower clamping force is suggested particularly if the printed mold is not protected by a metal frame. A broad range of thermoplastics can be injected with 3D printed molds such as TPE, PP, PE, ABS, POM, ASA, PA, PC, or TPU.

5. Injection

It may take a few shots to identify your ideal process conditions as many factors are at play including part geometry, choice of plastic, injection temperatures and pressures, and other parameters.

Reduce injection pressure and temperature as much as possible. With one printed mold, Formlabs users are usually injecting 100s of parts in easy to process plastics such as TPE, PP and PE with temperatures up to 250°C. With plastics that require higher injection temperature such as PA or PC, the 3D printed mold might have a shorter lifespan.

6. Cooling

The cooling time of a polymer printed mold is longer than that of a metal mold, as thermal transfer occurs slower in plastic than metal. As such, adding cooling channels to your printed mold is generally not suggested. Instead, cooling can be accelerated by applying compressed air or using interchangeable stacks.

7. Demolding

Demolding Demold the part either manually or automatically with ejector pins. Apply a release agent for thermoplastics with high viscosity. Mold releases are widely available and silicone mold releases, such as Slide or Sprayon product (Formlabs, n.d.).

For the larger production quantities there is only one solution and that is to externally manufacture the charger. This will be done with injection moulding, because it is a cost-efficient method for larger production quantities.

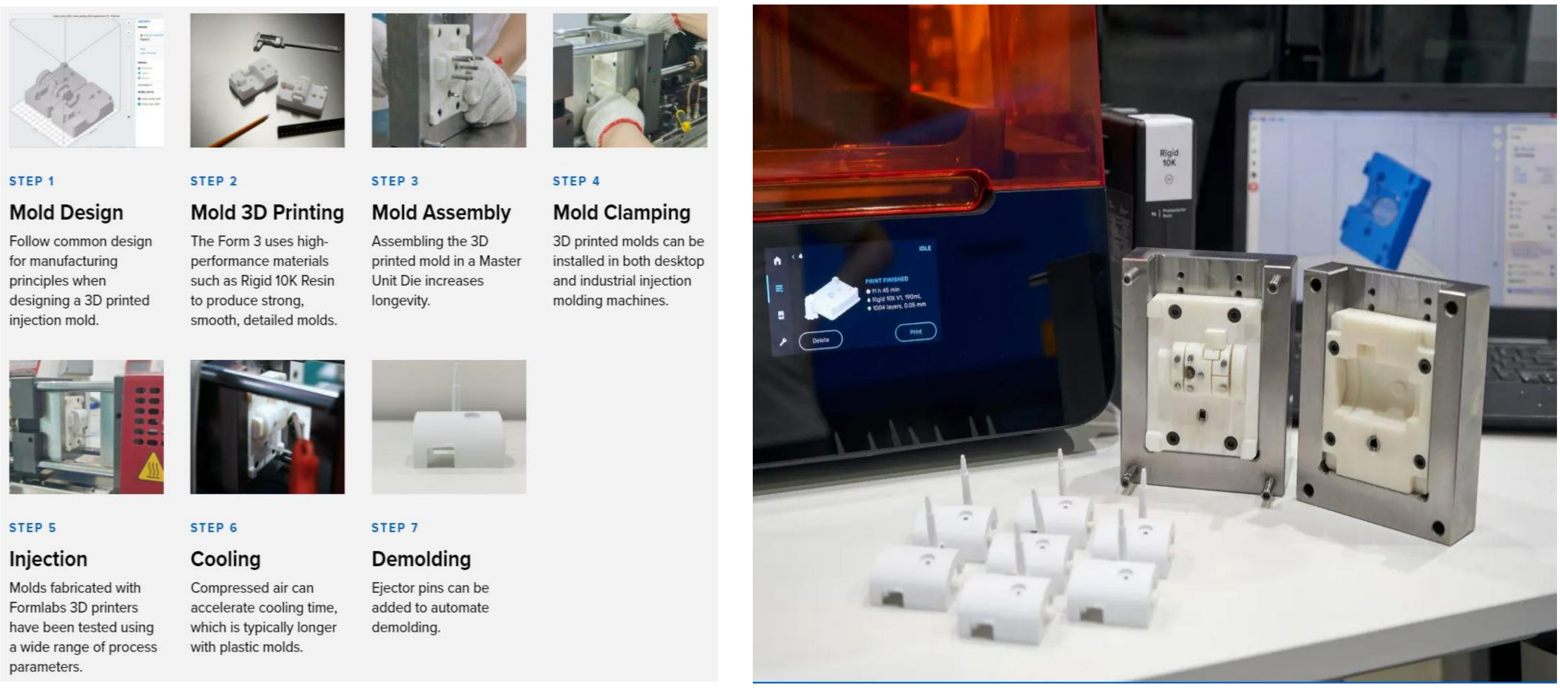


Figure 4.18 Mould development with the use of a resin 3D printer (Formlabs, n.d.)

Design of the molded product
1.Try to keep the shape simple as possible.
2) Make the thickness even.
3) Put a draft angle.
4) Do not make the sharp corner.
5) Try not to make the undercut.
6) Place a gas vent properly (Mitsubishi Engineering-Plastics Corporation, n.d.)

More helpful information:

1. Masterclass video about resin moulds

2. How to use 3D printed moulds

3. Design info for molded products

4. Different type of moulds

First batch manufacturing with SLS
The third method to produce the first batch of 300 charger units could be by utilizing the SLS printing method. This manufacturing technique is on lower batch volumes more feasible than SLA printing or injection moulding the parts. Because for injection moulding you require expensive or inexpensive moulds. These need to be designed and the company must require an injection moulding machine. This all adds up to the final production cost. Therefor SLS could be a great solution. The disadvantage of SLS printing is that the printed parts are limited by some materials and that the material like nylon is only available in a white colour. This means that the charger needs to be painted afterwards, also adding up to production complexity and costs.

The estimated production cost of SLS printing will be around €3 per charger chassis for printing with nylon. The price is an estimation and is based around the production of 300 units within Las Palmas de Gran Canaria. Production costs could very between country and production facility.

Common injection moulding design defects
There are several important factors to keep in mind while designing injection moulded parts. Because some defects can occur on injected moulded parts, decreasing the overall strength of the part and reducing the overall appearance of injected moulded object. Therefor the most common injected moulded defects are listed below.

Warping:
Warping can occur on a part when certain sections of an injection moulded product cools down. They will bend due to the stress. Parts with non-consistent wall thickness have more warping issues then parts with consistent walls (Hubs, n.d.). Therefor it’s important that the charger consists of uniform wall thickness to prevent the part from warping.

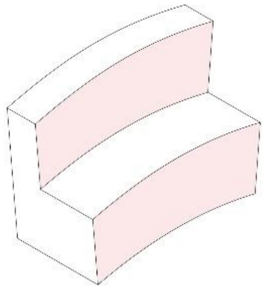


Figure 3.19 Warping (Hubs, n.d.)

Sink marks:
Sink marks can occur when a part not evenly solidifies. Small marks on a flat surface may appear. These marks are called Sink marks. This problem can be prevented to use recommended wall thicknesses (Hubs, n.d.).

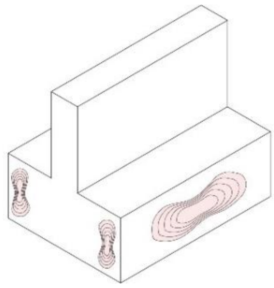


Figure 3.20 Sing marks (Hubs, n.d.)

Drag Marks
Drag marks can occur when plastic is injected in the mould and cools down. While shrinking it can slide and scrape against the mould, causing drag marks. This issue can be prevented by using draft angles instead of vertical walls (Hubs, n.d.).

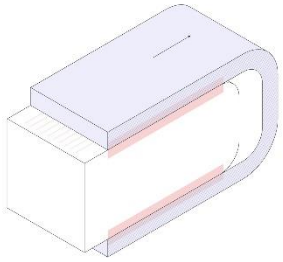


Figure 3.21 Drag marks (Hubs, n.d.)

Knit lines
Knit lines can occur when the plastic flow meets after flowing around a gap. This issue will decrease the strength of the part. Parts with abrupt geometry changes or holes are more prone to Knit Lines (Hubs, n.d.).

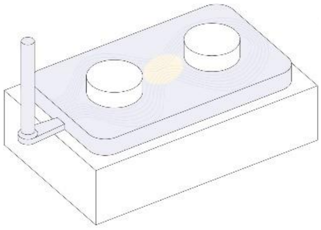


Figure 3.22 Knit Lines (Hubs, n.d.)

Short shots
Short shots can occur when air is trapped within a gap where it cannot escape. This can result in incomplete parts. Therefor it is important to design a mould with ventilation shafts where high pressure air can escape while the injection moulding. Also, parts with thin walls are more prone to short shots (Hubs, n.d.).

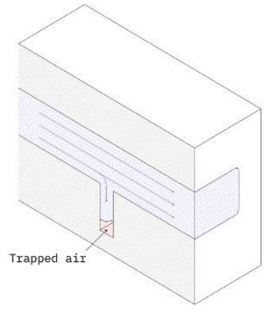


Figure 3.23 Short shots (Hubs, n.d.)

Injection moulding design guidelines
Before designing the charger, it is important to know what type of standard guidelines there are used for designing an injection moulded product. Like minimum outer wall thickness, corners radius, Draft angles, undercuts, and the utilization of bosses/ribs are important factors to keep in mind while designing the part.

Undercuts:
Undercuts are overhang objects like snap fittings without a whole where the object can go through after being injected moulded. Therefor it is important to design the parts without undercuts. If the undercuts cannot be prevented a sliding side-action mechanism (see figure 5.25 can be designed within the mould. But this will make the injection process more complicated and expensive.

Moving the parting line can also resolve undercuts in a design. When the seam is adjusted like in figure 5.26 the overhang issue is easily mitigated.

The last option to resolve an undercut is by using stripping undercuts (see figure 5.27). These must fallow the fallowing guidelines.

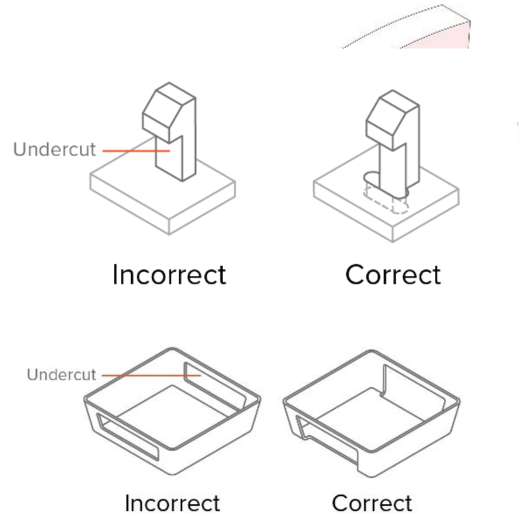


Figure 3.24 Undercuts and overhangs (Hubs, n.d.)

- The stripping undercut must be located away from stiffening features, such as corners and ribs.
- The undercut must have a lead angle of 30o to 45o degrees.
- The injection molded part must have space and must be flexible enough to expand and deform.

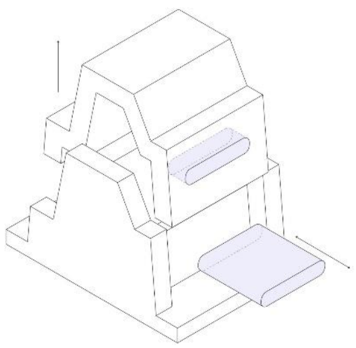


Figure 3.25 Side action mechanism (Hubs, n.d.)

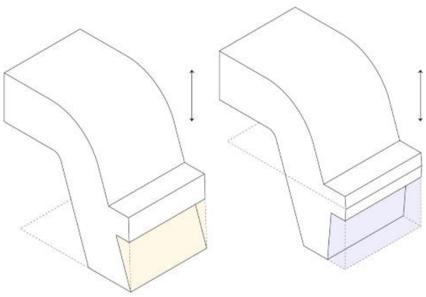


Figure 3.26 Seam line (Hubs, n.d.)

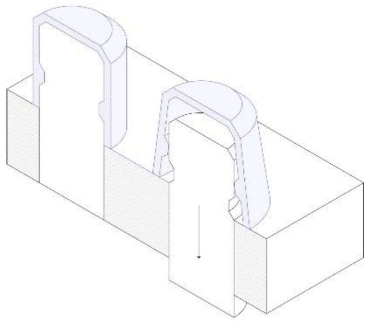


Figure 3.27 Stripping undercut (Hubs, n.d.)

Wall thickness (design):
The wall thickness of a design is an important factor to ensure that the final product is durable enough and lasts long. By using recommended wall thicknesses (see figure 3.28) while designing the charger will improve the overall lifespan of the product.

But the walls should not be too thick to prevent cooling down problems while injection moulding the design. Besides this, thicker walls will increase the cooldown period in the mould, what makes the manufacturing process longer and more expensive. Lastly, the material cost will also slightly increase because more raw plastic is required to fill, he moulds (Jaycon Systems, n.d.).

Resin	Recommended Wall Thickness (Inches)	Recommended Wall Thickness (mm)
ABS	0.045 – 0.140	1.143 - 3.556
Acetal	0.030 – 0.120	0.762 - 3.048
Acrylic	0.025 – 0.150	0.635 - 3.81
Liquid crystal polymer	0.030 – 0.120	0.762 - 3.048
Long-fiber reinforced plastics	0.075 – 1.000	1.905 - 25.4
Nylon	0.030 – 0.115	0.762 - 2.921
Polycarbonate	0.040 – 0.150	1.016 - 3.81
Polyester	0.025 – 0.125	0.635 - 3.175
Polyethylene	0.030 – 0.200	0.762 - 5.08
Polyphenylene sulfide	0.020 – 0.180	0.508 - 4.572
Polypropylene	0.025 – 0.150	0.635 - 3.81
Polystyrene	0.035 – 0.150	0.889 - 3.81
General rule of thumb	***0.040–0.140***	***1.016 - 3.556***

Figure 3.28 Recommended wall thickness (Jaycon Systems, n.d.)

Sharp Edges:
Sharp corners put stress on the parts, this can lead to part failure. To resolve this issue, parts should have rounded corners. It is advised to have an inner radius Ri=1/2*T. So, the radius should be half the thickness of the wall rounded and the outer radios should be Ri=3/2*T (see figure 4.29).

If the design has different wall thicknesses that cannot be avoided, then it is advised to use smooth transitions. These smooth transitions are called chamfers or fillets and must be rounded (see figure 4.30)

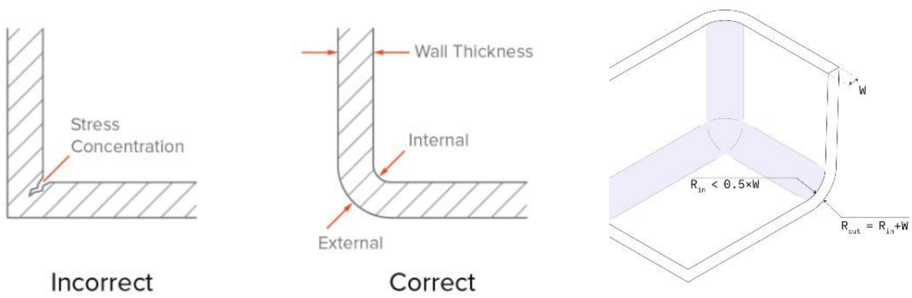


Figure 3.29 rounded and sharp corners (Hubs, n.d.)

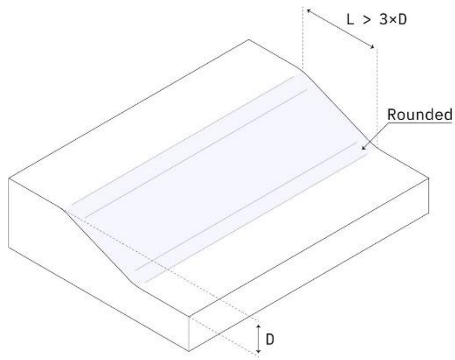


Figure 3.30 Smooth transition (Hubs, n.d.)

Utilization of ribs and bosses for structure
Ribs and bosses add a lot of structure to the final product. This improves the durability of the final product. Without any supports the walls could be fragile and collapse (see figure 4.31).

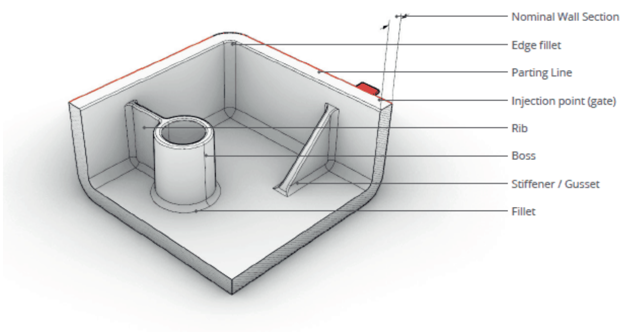


Figure 3.31 Ribs and bosses

Draft angles:
Most product designs have straight outer walls, but straight walls cannot be easily injected moulded. This is because of the release mechanism of an injection moulding machine. Therefor almost all injected moulded parts need to have a slight angle to (see figure 3.32 and 3.33) make the release of the product possible without damaging the sides (Shak Akhrarov, n.d.). [Watch video]() about how to design with draft angles.

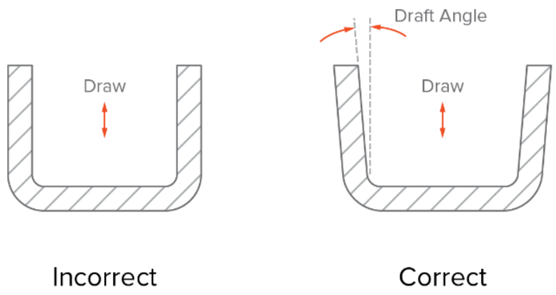


Figure 3.32 Draft angles (Hubs, n.d.)

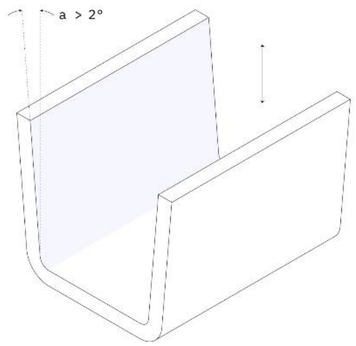


Figure 3.33 Draft angles (Hubs, n.d.)

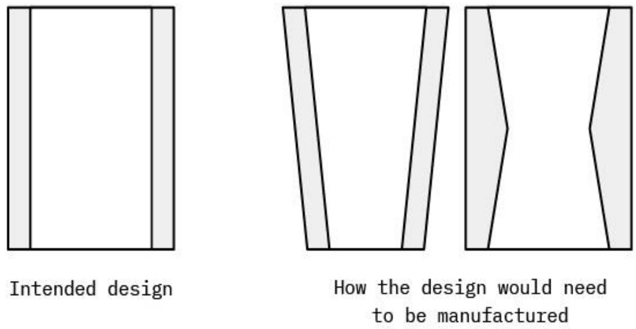


Figure 3.34 Draft angles with and without friction (Shak Akhrarov, n.d.)

Material shrinkage:
Plastic material shrinks after a moulded part cools down after injection. Different type of plastic materials has also different shrink rates depending on resin family (amorphous vs crystalline materials), mould design and processing condition (plastic components, n.d.). Pease see figure 3.35 about plastic shrink rate.

Material	Recommended Tonnage (per in²)	Shrink Values	Vent Depth (in.)
Acrylonitrile Butadiene Styrene (ABS)	2.5 – 3.5	.004 - .008	.0010 - .0020
ABS/Polycarbonate Blend (PC/ABS)	3.0 – 4.0	.004 - .007	.0015 - .0030
Acetal (POM)	3.0 – 4.0	.020 - .035	.0005 - .0015
Acrylic (PMMA)	3.0 – 4.0	.002 - .010	.0015 - .0020
Ethylene Vinyl Acetate (EVA)	2.0 – 3.0	.010 - .030	.0005 - .0007
Ionomer	2.5 – 3.5	.003 - .020	.0005 - .0007
High Density Polyethylene (HDPE)	2.5 – 3.5	.015 - .030	.0008 - .0010
Low Density Polyethylene (LDPE)	2.0 – 3.0	.015 - .035	.0005 - .0007
Polyamide - Nylon (PA) Filled	4.0 – 5.0	.005 - .010	.0003 - .0010
Polyamide - Nylon (PA) Unfilled	3.0 – 4.0	.007 - .025	.0005 - .0020
Polybutylene Terephthalate (PBT)	3.0 – 4.0	.008 - .010	.0005 - .0015
Polycarbonate (PC)	4.0 – 5.0	.005 - .007	.0010 - .0030
Polyester	2.5 – 3.5	.006 - .022	.0005 - .0010
Polyetheretherketone (PEEK)	4.0 – 5.0	.010 - .020	.0005 - .0007
Polyetherimide (PEI)	3.0 – 4.0	.005 - .007	.0010 - .0015
Polyethylene (PE)	2.5 – 3.5	.015 - .035	.0005 - .0020
Polyethersulfone (PES)	3.0 – 4.0	.002 - .007	.0005 - .0007
Polyphenylene Oxide (PPO)	3.0 – 4.0	.005 - .007	.0010 - .0020
Polyphenylene Sulfide (PPS)	3.5 – 4.5	.002 - .005	.0005 - .0010
Polyphthalamide (PPA)	3.5 – 4.5	.005 - .007	.0005 - .0020
Polypropylene (PP)	2.5 – 3.5	.010 - .030	.0005 - .0020
Polystyrene (PS)	2.0 – 2.5	.002 - .008	.0015 - .0020
Polysulphone (PSU)	4.0 – 5.0	.006 - .008	.0010 - .0015
Polyurethane (PUR)	2.5 – 3.5	.010 - .020	.0004 - .0010
Polyvinyl Chloride (PVC)	2.5 – 3.5	.002 - .030	.0005 - .0020
Thermoplastic Elastomer (TPE)	2.5 – 3.5	.005 - .020	.0008 - .0010

Figure 3.35 Plastic shrink rate

Injection moulding sprue and runner sizes:
Using circle shaped and short sprue is preferred. The minimum of the sprue diameter is 5mmφ, and normally, use sprue with diameter of 7~8mmφ. To take out the sprue easily, put a 3°to 5°taper on the inner diameter of the sprue bush. Quench the sprue bush and to prevent getting out, hold it with the locate ring. Also, curvature radius of sprue bush spherical surface void, should be little bigger than the curvature radius of nozzle head. To make the flow of the melting resin smooth and even, the runner should be as thick as possible, short, placed well, and each corner should be round so that flow resistance will become smaller. When the melting resin flows through the runner, the resin close to the cold mold will solidify by decreased temperature. This solidified resin will work as a heat insulator, and the melting resin will flow through it. Therefore, a circular runner is the ideal. In the case of two plates mold, use a circular runner if the parting face is flat, and use a trapezoidal runner if not or if the mold has three plates. Also, place the cold slug well on the bottom of the sprue (Mitsubishi Engineering-Plastics Corporation, n.d.).

average venting depth for mould design:

Material	The Venting Depth (mm)
ABS	0.025-0.038
POM	0.013-0.025
PMMA	0.038-0.005
PA	0.008-0.013
PC	0.038-0.064
PET/PBT	0.013-0.018
PE	0.013-0.030
PP	0.013-0.030
GPPS	0.018-0.025
HIPS	0.020-0.030
PVC	0.013-0.018
PU	0.010-0.020
SAN	0.025-0.038
TPE	0.013-0.018

Figure 3.36 Venting depth (mm)

The mold vent should be designed on the cavity side of the parting surface, in order to facilitate mold manufacturing and cleaning. Try to set it at the end of the material flow and the thicker section of the plastic part. The venting direction should not face the operator, but should be machined into a curve or bend, to prevent the operator from being burnt during gas injection. The vent usually measures 1.5 to 6 mm in width, and 0.02 to 0.05mm in depth. It is preferred that the plastic material does not enter the vent. (Mold Venting System & Design Principles, n.d.)

3.11 Material research (Design for manufacturing)
Prototyping materials:
FDM printing:
The prototypes that are made with the FDM printer use polylactic Acid (PLA) as main material. This material is affordable and relatively easy to print with. The PLA printing temperatures are between 190-210 degrees. PLA is also partly biodegradable and is created from renewable biomass products like corn (O'Connell & M. Bohlooli, 2021).

> Polylactic Acid is biodegradable and has characteristics similar to polypropylene (PP), polyethylene (PE), or polystyrene (PS). It can be produced from already existing manufacturing equipment (those designed and originally used for petrochemical industry plastics). This makes it relatively cost efficient to produce. Accordingly, PLA has the second largest production volume of any bioplastic (the most common typically cited as thermoplastic starch) (Tony Rogers, 2015)

SLA printing:
For the main SLA prints there will be used UV resin from Anycubic. These resins cure when UV light is projected layer by layer. For the development of the mould there will be used flexible resin that has a high temperature resistance (see figure 3.37). This is important because moulded plastic is injected in the resin mould.

> Anycubic resins are all exclusively made for DLP, making them unsuitable for SLA. The reason for this is that DLP resins are especially sensitive to light so that they can work with the low-power light sources found in DLP 3D printers. SLA printers use much higher-powered light sources (lasers), which require a different chemical composition in the material (Leo Gregurić, 2019).

Figure 3.37 Flexible 3D printed resin

Manufacturing:
List of most common materials used for plastic injection moulding:

- Acrylic or Polymethyl Methacrylate (PMMA)
- Polycarbonate (PC)
- Polyethylene (PE)
- Polypropylene (PP)
- Polyethylene Terephthalate (PETE or PET)
- Polyvinyl Chloride (PVC)
- Acrylonitrile-Butadiene-Styrene (ABS)

> However, the list doesn't end here. There are a variety of materials available. That's why choosing the right plastic material for your custom injection molding project is an important decision. Plastic materials look and behave differently based on the characteristics of their chemical makeup. Based on the part's intended application and functionality, important material properties must be considered, such as durability, flexibility, performance, texture, density and color.
>
> It is also essential to look at each material's shrinkage and mold flow rate. Understanding these criteria can mitigate undesirable defects such as warpage, sink marks and color streaks, which can affect the part's dimensions, tolerances and surface finish (icomold, 2021).

Material best suited for the charger:

Before choosing a production material for the charger it is important to consider government regulations, the material performance, aesthetics, cost, machinability, intellectual properties, reliability, and the industry standards (see figure 3.3).

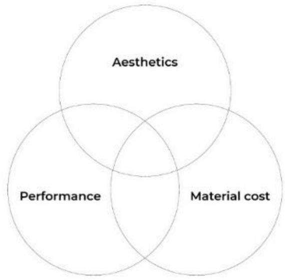


Figure 3.38 Diagram

Common production materials for injection moulding:

These materials listed below could be used for manufacturing the charger. All the materials have different type of material properties, performances, cost and aesthetics that need to be taken in consideration when choosing the best material suited for the charger.

1. Polyethylene – PE

Polyethylene (PE) is the most popular plastic in the world, and accounts for 34% of the total plastics market. There is low-density polyethylene (LDPE) and high-density polyethylene (HDPE). LDPE is manufactured with high pressure and high temperature, whereas HDPE is manufactured with relatively low pressure and low temperature. So be sure to considering LDPE injection molding or HDPE injection molding with your next project .

LDPE is the most flexible type of polyethylene, and it is widely used in packaging. It provides superior moisture resistance, although it should not be used in harsh weather or high temperature conditions. It has high impact strength and good chemical resistance. It is a low-cost option that can be easily processed by most methods.

This versatile resin is used for many everyday products such as plastic bags, plastic films, bottles, containers, lids and caps. It is also used to make six-pack rings, toys and computer components. It is often recycled and made into items such as trash cans, floor tile, paneling and furniture.

2. Polypropylene – PP

Polypropylene (PP) is the second most widely-produced plastic in the world, after polyethylene (PE). Its behavioral characteristics are similar to PE, but it is slightly harder and more heat-resistant. It is a commodity grade polymer popular in the packaging and labeling industries.

PP is tough, fatigue- and chemical-resistant, but vulnerable to UV radiation and it is flammable. It is a versatile plastic, as it is easily customized with additives. It is naturally white.

Due to the elasticity of PP, it makes a good material for living hinges. It is also used in many common items such as buckets, packaging, bottle caps, toys and many other items.

3. Acrylonitrile Butadiene Styrene – ABS

Acrylonitrile butadiene styrene (ABS) is also one of the most common, widely-used plastic material in the world. ABS plastic molding is often a standard when it comes to mold making. Impact resistance and toughness are the two most important material characteristics of ABS, and those qualities make it such a popular, low-cost, commodity-level thermoplastic polymer. It is used in a wide range of products in the automotive, appliance and electronics industries, among many others (icomold, 2021).

ABS provides superior strength and temperature resistance. It combines the strength and rigidity of acrylonitrile and styrene polymers with the toughness of polybutadiene, a rubbery material, even at low temperature. The styrene gives the plastic a shiny, colorfast, high-quality surface finish. ABS molding is on direction to consider.

Polyoxymethylene – POM
Polyoxymethylene (POM) is also commonly known as acetal, and also known as polyacetal and polyformaldehyde. It is considered an engineering grade thermoplastic, a step up from commodity plastics in performance and price. It provides high stiffness, excellent dimensional stability, and is used for precision parts requiring low friction.

POM provides high strength, rigidity and hardness, and it is resistant to chemical solvent. It is opaque white in its natural state, but it is easy to color to any color.

POM is a good choice for high-performance components like small gears and bearings, and other applications where the component comes in contact with other parts, such as plastic gears and ball bearings. It is commonly used in the automotive and consumer electronics industries, and it is used in eyeglass frames, guns, knife handles and other items that require strength and toughness.

Polystyrene – PS
Polystyrene (PS) is a widely-used polymer that can be either solid or foamed. As a solid, it is used to make things like disposable cutlery, and in its foam state (Styrofoam) it can be extruded to make things like packing peanuts and disposable drinking cups.

PS is clear, hard, and fairly brittle (think of how easily the tines can break off of a plastic fork). It is naturally transparent, but can be colored with colorants. It is not biodegradable, so many PS items, especially “single-use” items, contribute to the world’s litter problem. It is also used to make CD jewel cases, license plate frames and plastic model kits (icomold, 2021).

Material	*Aesthetics*	*Performance*	*Material Cost*	*Industry standard*	*Total*
Points multiplier	***5***	***5***	***3***	***3***	
Polyethylene – PE	*3*	*3*	*3*	*9*	*84*
Polypropylene – PP	*3*	*1*	*9*	*3*	*56*
Acrylonitrile Butadiene Styrene – ABS	*9*	*9*	*3*	*3*	*108*
Polyoxymethylene – POM	*9*	*3*	*3*	*1*	*102*
Polystyrene – PS	*1*	*1*	*9*	*3*	*46*

Table 3.3 Matrix about material options

Material conclusion:
From the table you can see that acrylonitrile Butadiene styrene (ABS) is overall the best performing material to produce the charger on a larger scale. The material is an engineering thermoplastic that is widely used in electronic housing, consumer products and different kind of car parts. The material has a relatively low melting point and has a high heat resistance what makes it perfect for the charger. Besides that, the material can easily be used in the low production version of the charger as well, because of its unique characteristics that make it possible to produce with more affordable injection molding machines.

3.12 Surface finishing

Injected moulded ABS plastic has a shiny characteristic. But when you apply a texture to a mould it will result in a textured part. This can enhance the aesthetics of the final product and offer extra features like grip, fingerprint, and/or more scratch resistance. But texturing a mould will also increase production complexity, cost and overall production time. This has to do with the extra steps needed to make the mould and the extra increased cooldown time.

Figure 3.39 Plastic texture difference

Important factors:

- Surface roughness
- Texture topology
- Surface texture
- Finishing

[Video](#) 1 about moult texturing
[Video](#) 2 about engraving mould-tech

The Society of Plastics Industry (SPI) explains several standard finishing procedures that result in different part surface finishes (see figure 3.40). (Hubs, n.d.)

Finish	Description	SPI standards*	Applications
Glossy finish	The mold is first smoothed and then polished with a diamond buff, resulting in a mirror-like finish.	A-1 A-2 A-3	Suitable for parts that require the **smoothest surface finish** for cosmetic or functional purposes (Ra less than 0.10 μm). The A-1 finish is suitable for parts with mirror-like finish and lenses.
Semi-gloss finish	The mold is smoothed with fine grit sandpaper, resulting in a fine surface finish.	B-1 B-2 B-3	Suitable for parts that require a **good visual appearance**, but not a high glossy look.
Matte finish	The mold is smoothed using fine stone powder, removing all machining marks.	C-1 C-2 C-3	Suitable for parts with **low visual appearance requirements**, but machining marks are not acceptable.
Textured finish	The mold is first smoothed with fine stone powder and then sandblasted, resulting in a textured surface.	D-1 D-2 D-3	Suitable for parts that require a **satin or dull textured** surface finish.
As-machined finish	The mold is finished to the machinist's discretion. Tool marks will be visible.	-	Suitable for **non-cosmetic parts**, such industrial or hidden components.

Figure 3.40 SPI standards sheet

When selecting a glossy surface finish, remember these useful tips:

- A high glossy mold finish is not equivalent to a high glossy finished product. It is significantly subject to other factors such as plastic resin used, molding condition and mold design. For example, ABS will produce parts with a higher glossy surface finish than PP. To find the recommended material and surface finish combination visit the appendix.

- Finer surface finishes require a higher grade material for the mold. To achieve a very fine polish, tool steels with the highest hardness are required. This has an impact on the overall cost (material cost, machining time and post-processing time) (Hubs, n.d.)-

3.13 Different joining mechanisms for plastic (Design for manufacturing)

The charging circuit board needs to be placed and fitted securely within the charger housing. Therefor a top part is required. The top will secure and protect the charging board from damages. To make sure that the final design can also be dissembled for repairs and recycling purposes there needs to a way to secure the top part with the bottom part.

Different solutions:

1. Straight beam snap mechanism
2. Tapered beam snap mechanism
3. Full perimeter snap in mechanism
4. Snap op mechanism
5. Prolonged snap in mechanism
6. Ball or cylinder snap in mechanism
7. Glue mechanism
8. Screw method

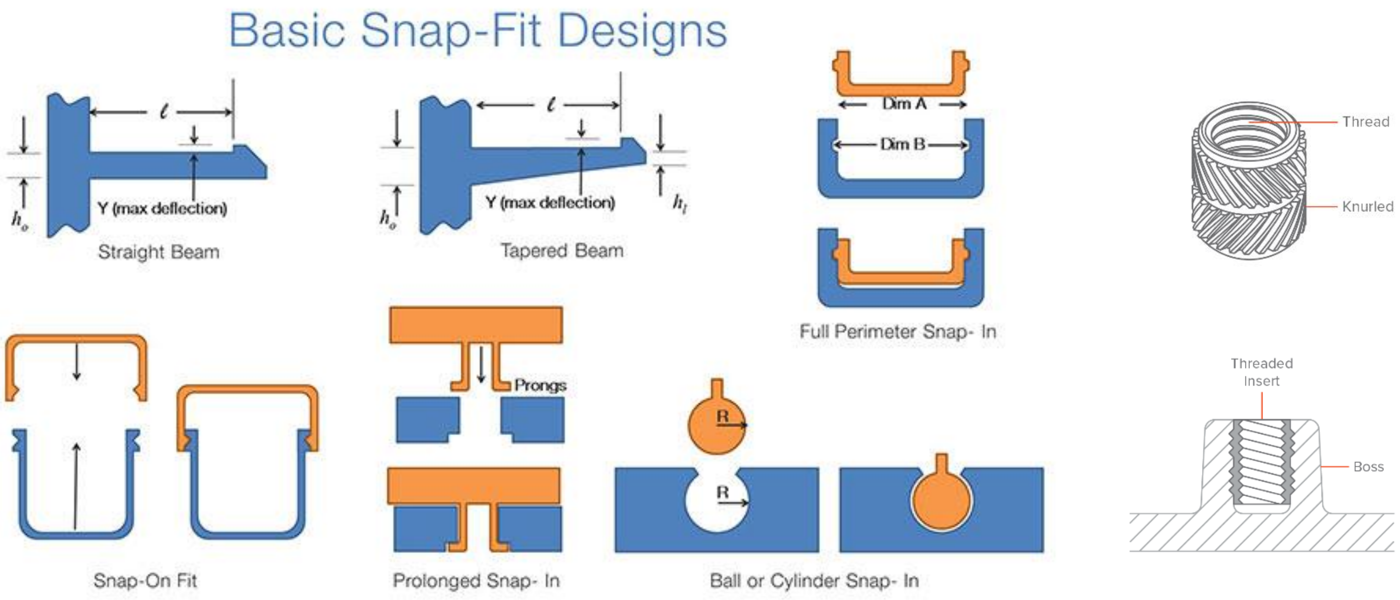


Figure 3.41 Different join mechanism

Conclusion:
The most cost-effective solution is gluing the parts together, but when repairability and recyclability is an important factor then a straight snap mechanism or thread mechanism would be the best solution. These connection options will ensure that the internals of the charging board are well protected.

3.14 Design requirements charger

All standard design requirements are listed below, these are based on the CTQ's from the customers, other measured and analysed research. The charger must be verified with these requirements to make sure that the final version of the charger will function as required (see table 3.4).

Table 3.4 Design requirements

Functional requirements of the first charger	Design Parameters and KPI´s
The charger will not damage the hardware wallet	Minimal friction (only sides and connecter point)
The max weight of the charger is	<50 gram
Minimal operational temperature	0-40 °C
The charger must have a USB connector	Type C
The dimensions of the charger must fit in the current packaging dimensions	85x 54 x 15 mm (L*W*H)
Material of the charger	Nylon or ABS

Functional requirements of the final charger	Design Parameters and KPI´s
The charger will not damage the hardware wallet	Minimal friction (only sides and connecter point)
The max weight of the charger is	<50 gram
Minimal operational temperature	0-40 °C
The charger must have a USB connector	Type C
The dimensions of the charger must fit in the current packaging dimensions	85x 54 x 15 mm (L*W*H)
Material of the charger	ABS

Operational requirements of the first and final chargers
The charger must be easy to use
The charger must work with the new HASHWallet design
The charger will not damage the hardware wallets
The charger is portable and easy to carry
The LED indication lights are not obstructed while charging
The battery health is not influenced by the charging method (under normal conditions)
The dimensions of the charger must fit in the current packaging dimensions
The charger does offer minimal to no wear on the HASHWallet
The charger must charge faster than using the wireless charging method
The charger must be functional while charging
Charger parts can be injected moulded

4. Design phase

4.1 First 3D model

This 3D visualisation was created by an external motion graphic designer that supported the project team, for reference see figure 4.1. The visualisations and 3D designs are made in Modo. The 3D designs were made to analyse if it is possible to place al the electronic parts within the charger.

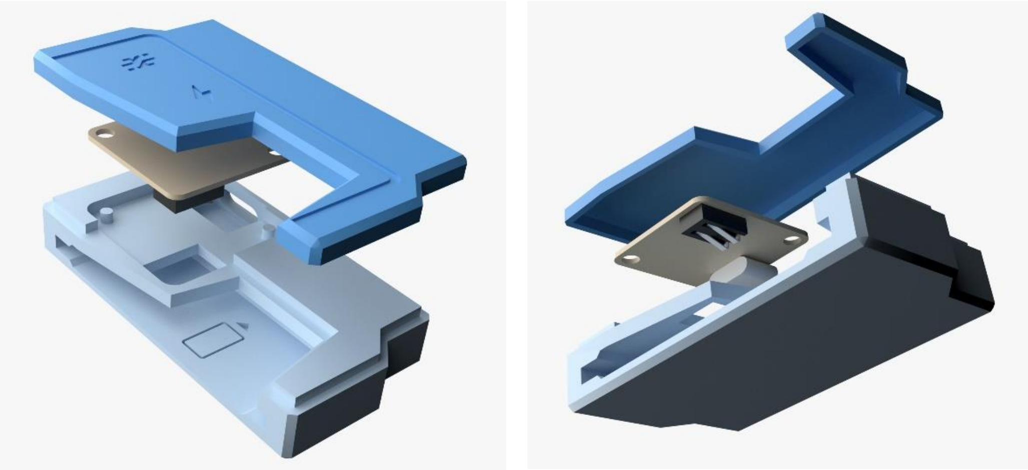


Figure 4.1 First 3D charger design

4.2 First 3D prototype

The first 3D models were printed with an SLA 3D printer to check if the model is also working and if the HASHWallet is charging correctly (see figure 4.2.1). The charger charged the HASHWallet, but there were some problems with the dimensions, so the card did not fit in well. Besides that, the LED lighting was not easily readable and the USB-C port on the circuit board did break after a few times of using the charger (see figure 4.2.1). This problem was caused by having too much room for the USB-C connection port. Therefor it was important that the 3D model needed to be adjusted.

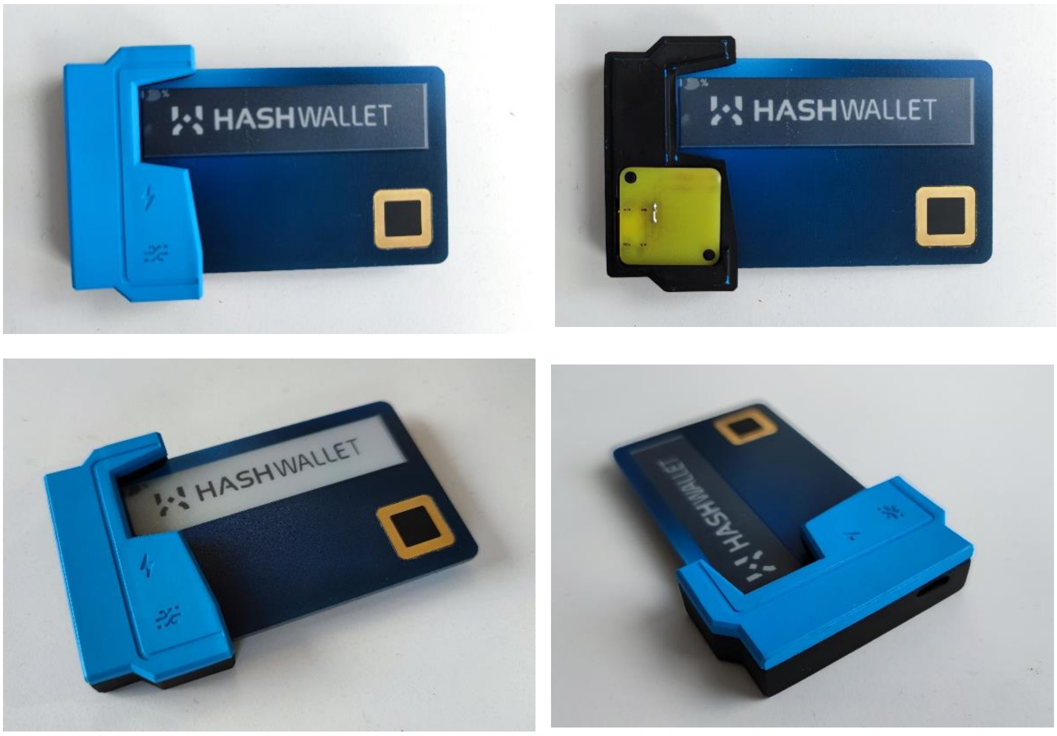


Figure 4.2.1 First 3D printed protype

Figure 5.2.2 USB-C alignment and broken charger part

4.3 Second 3D model

After creating a new 3D model from scratch, it was important that the design had some improvements over the first test version that was created by the motion 3D designer. This version should be created as a charger that can be used within the office for testing purposes and on events. The new project team was responsible for the newer version and it was created within Autodesk 3ds max (see figure 4.3) a different program then the external 3D designer used, but the two programs are very similar. The visualisation renders are done with a different plug-in render engine that works with Autodesk 3ds Max.

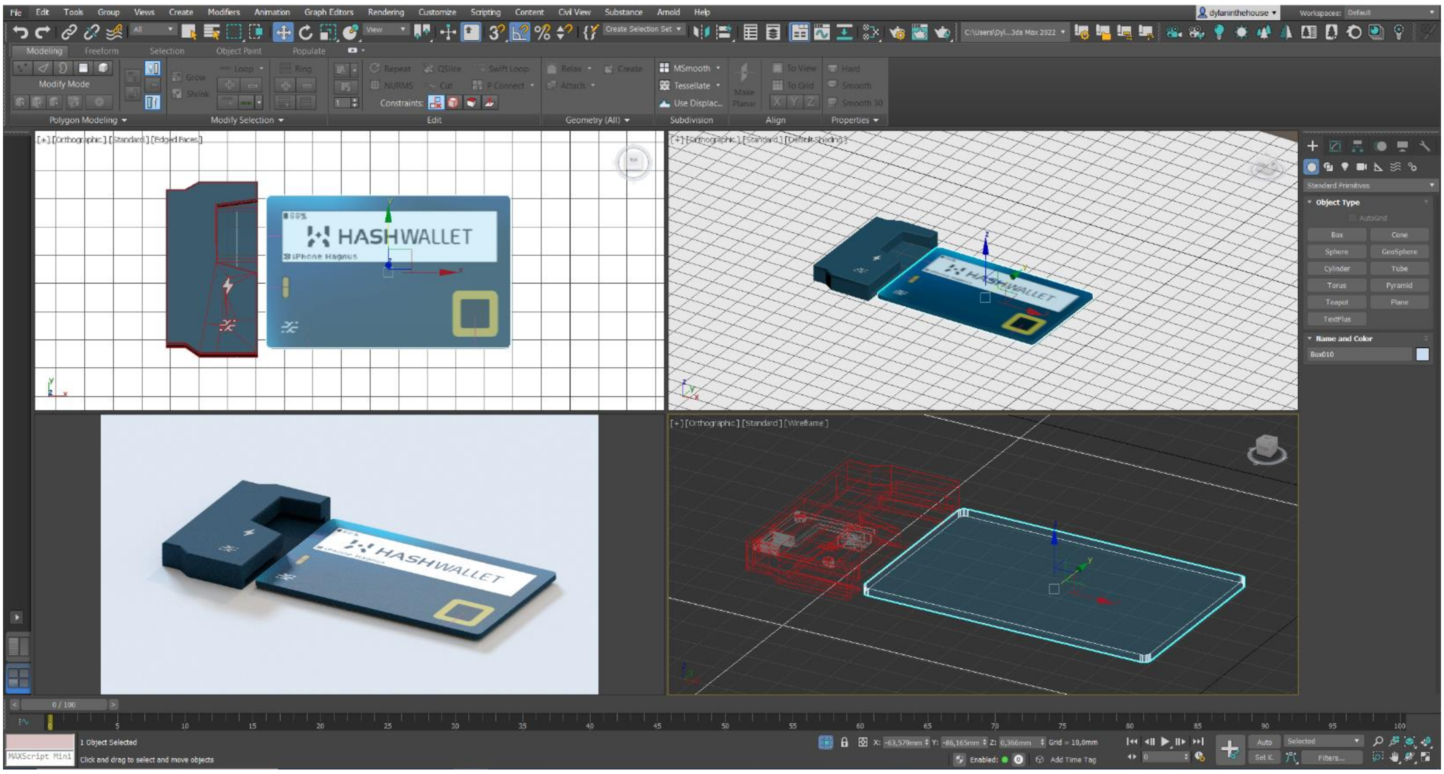


Figure 6.3 3ds max viewport

4.4 Visualisations of the second 3D model

As mentioned before the 3D visualisation renders are made with a render engine plug-in within 3ds max. With the help of 3D visualisations, it is easier to see how the final product/result will look. That is why 3D visualisations are common to use within product development, see figure 4.4 for the results.

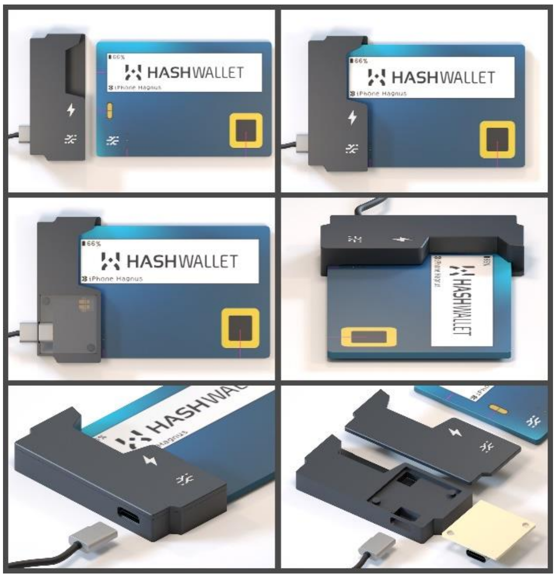


Figure 4.4 Visualisations of the first test version

4.4 Changes to the design

After checking the visualisations and dimensions it was clear that the problem with the LED indication lighting was still not resolved and that the model could more resemble the first concept design. After this the project team has changed the model a bit so that the LED indication lighting is visible and that the design resembled more the concept version of the card (see figure 4.5).

For these design changes it was necessary to change the bottom part of the charger where the circuit board is placed. This makes the design more fragile, because the outer layer of the charger is thinner (see figure 4.6). Therefor it is important to check if the protype is strong enough.

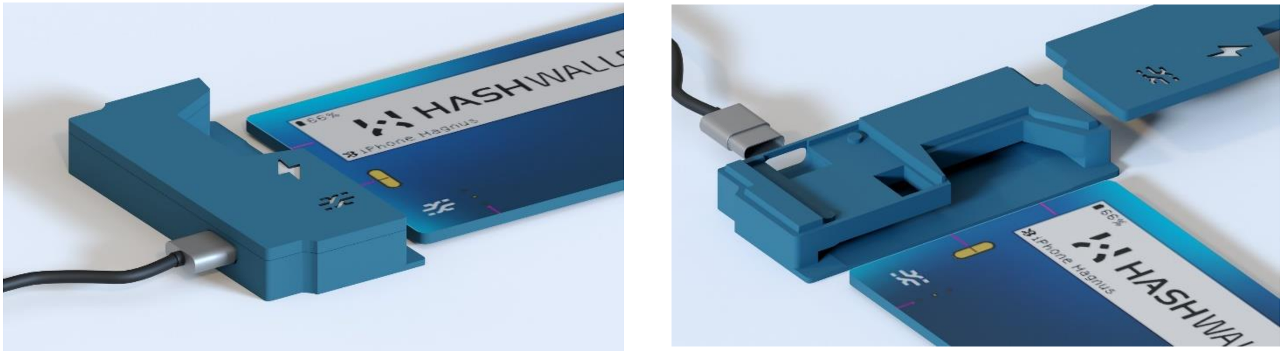


Figure 4.5 Updated design

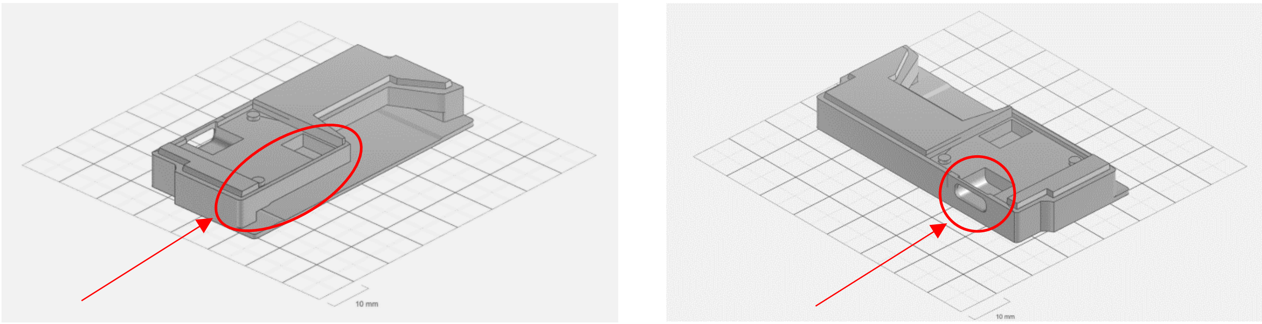


Figure 4.6 Fragile parts of the design

Design changes:

In figure 4.7 you see the changes that have been made to the 3D model. The newer version resembles more to the prototype drawing, the top part can be connected to the bottom part and LED indication lights are better visible. But this comes with the disadvantage that the design is more fragile than the previous version.

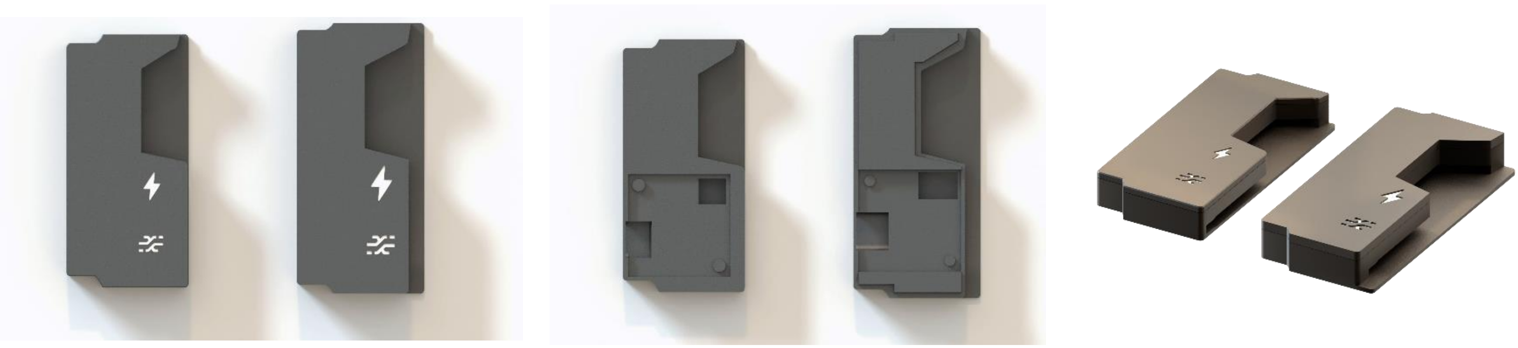


Figure 4.7 Design changes for the LED indication lights

4.5 Slicing the 3D model in Cura

Before printing a 3D model, it needs to be sliced within a slicer software like Cura. This software packages makes sure that a FDM 3D printer knows how a 3D model needs to be printed. This does the software by slicing a 3D model and giving it layers with a path, which a 3D printer can fallow.

In figure 4.8 Is the first version of the charger sliced. The bottom part is placed vertical to mitigate the bridging problem that all 3D printers are struggling with (Ultimaker, n.d.).

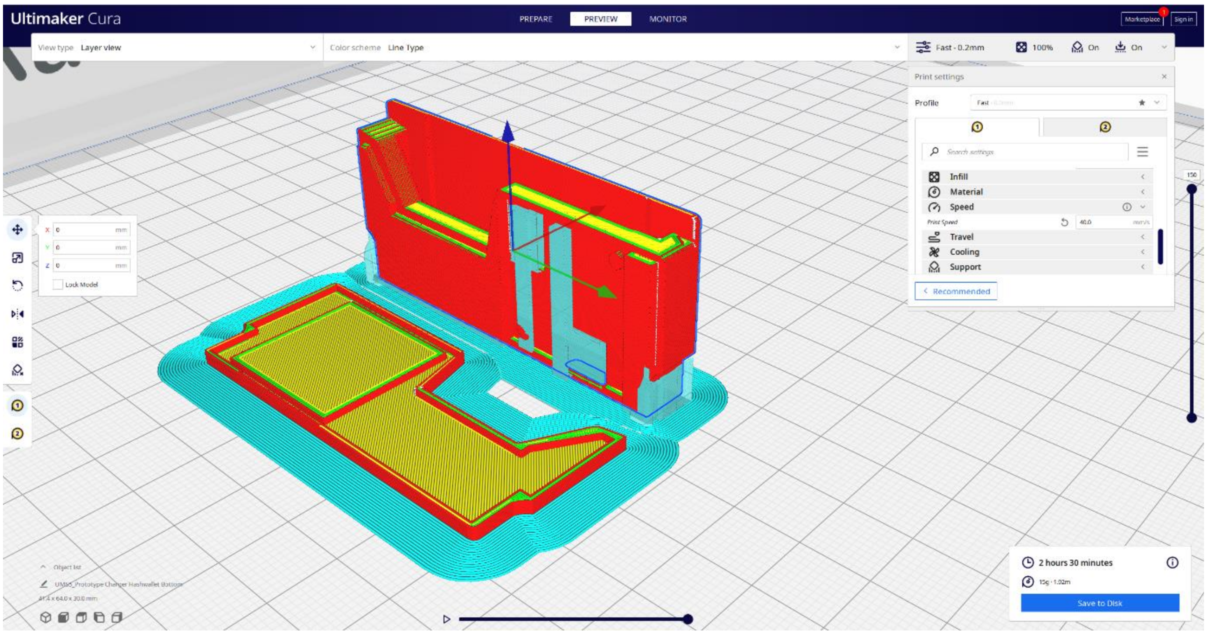


Figure 4.8 Cura slicing software

4.6 3D printing the first prototype

The second 3D protype is printed with a 3D printer from a team member that works with the hardware development team. The 3D print resembles a prototype but has some issues like a lower print quality then from a (M)SLA 3D printer, because this model is printed on a FDM printer.

Solving prototype issues:

To increase the development speed of the project and prototype quality, it was advised to invest in an affordable (M)SLA 3D printer for in the office in Las Palmas de Gran Canaria, this has been approved by Daniel (project lead). With this addition the prototypes do not have to be shipped weekly around what will improve the development speed and on the long run will save transport costs as well.

Figure 4.9 Second 3D prototype (FDM printer)

4.7 Changing design to make it more durable
To ensure that the chrager is more durable at the back part where the USB-C port bridges, the design has been made a bit thicker at the back. The border width is now 2 milimeter instead of 1 milimeter. Furthermore the front two sides, where the HASHWallet enters have been extented to match the sided (see figure 4.10 in comparision to figure 4.7). This makes entering the HASHWallet easier.

But still this design has a thinner front part, because the indication LED lights of the HASHWallet need to be visable to make operation of the card possible while charging. Therefor it is important to test the durability of this side of the first version of the charger.

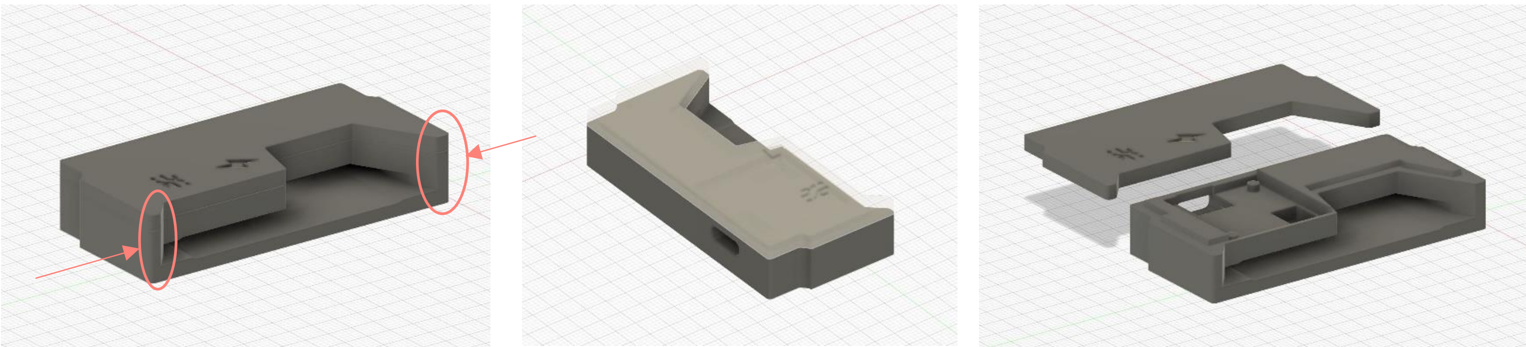


Figure 4.10 Adjusted 3D design (thinker walls and adjusted sides)

Prototyping:
The third version is visible on the left side and the second version of the design is visable on the right side of figure 4.11 (first image).

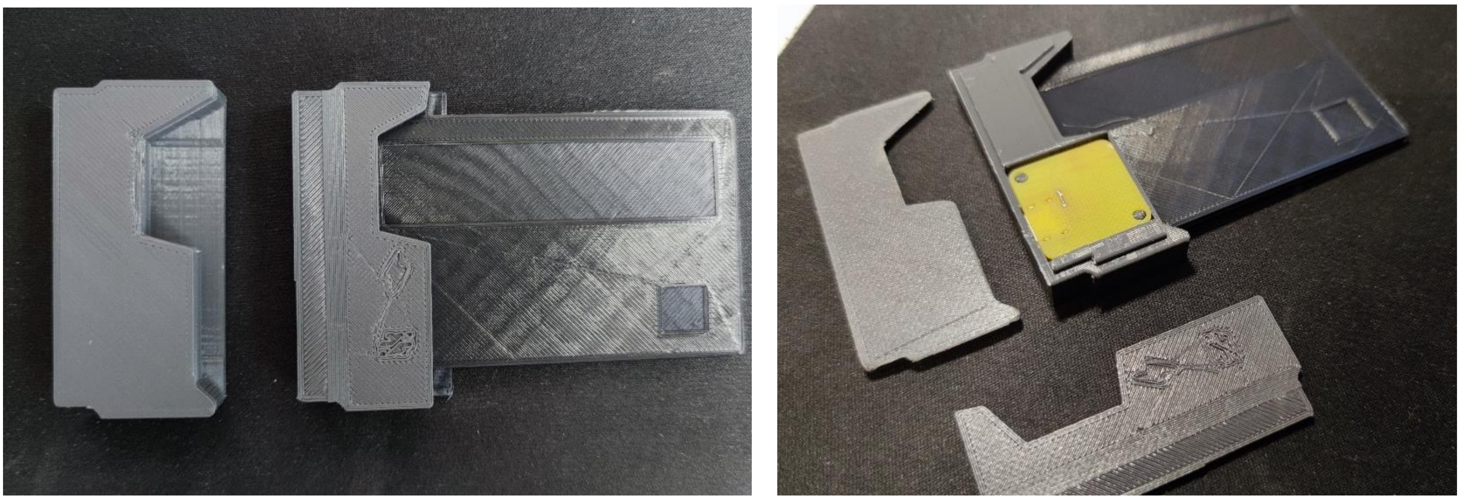
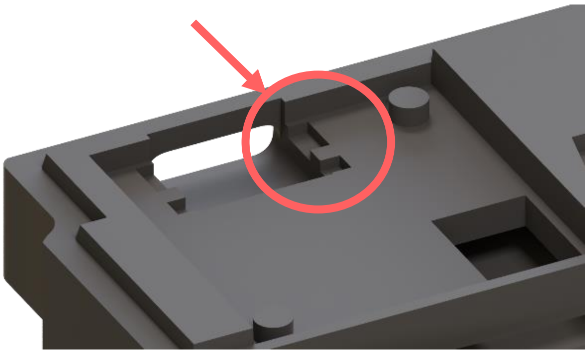


Figure 4.11 Adjusted design

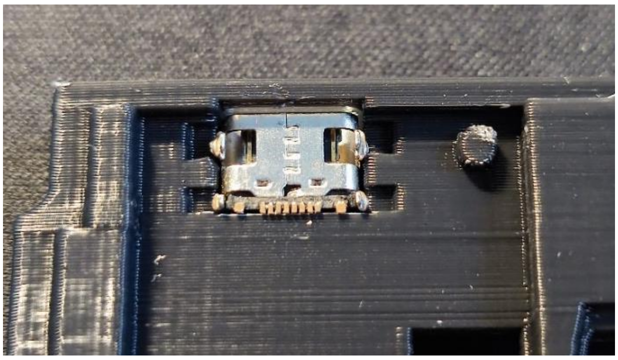
Conclusion:
The design does work from a technical standpoint but does not really fit the appearance. It looks quite bukly in comparison to the older versions. This is why the sides will be reajusted like it was on the older versions of the designs.

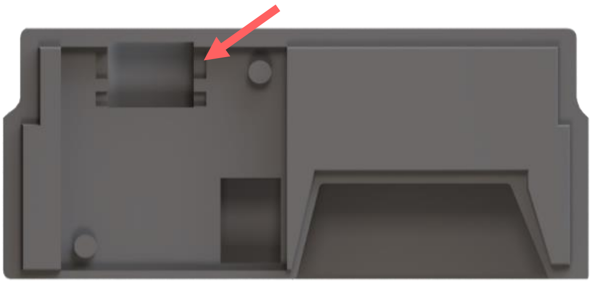
4.8 USB-C redesign first version

The sides where to large what did not fit the final appearance of the charger. Therefor the older design was updated to improve the durability. The sides where slightly adjusted and the USB-C port has now four holes, so that the USB port can be lowered the correct position. In the older versions this was not possible, because the USB-C port has connectors on the side.



This has been resolved by adding some extrusions to the 3D model (see figure 4.12). This will also increase the lifespan of the charging port by reducing friction.





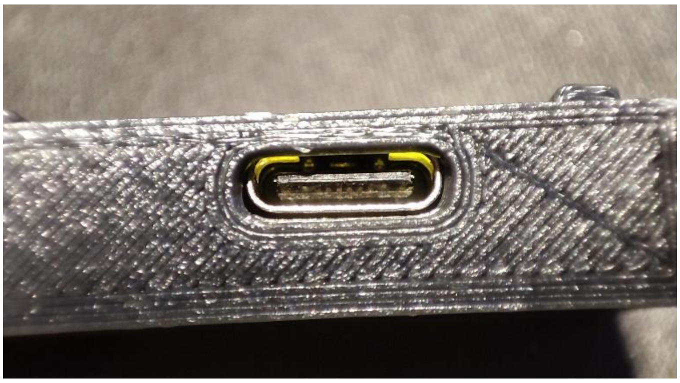


Figure 4.12 New design with better USB-C port holes

The thickness of the top part where the contact points are located has been reduced. This will secure the HASHWallet within the charger better, giving it more grip and making sure that current is going through the circuit board to the HASHWallet 8see figure 4.13.

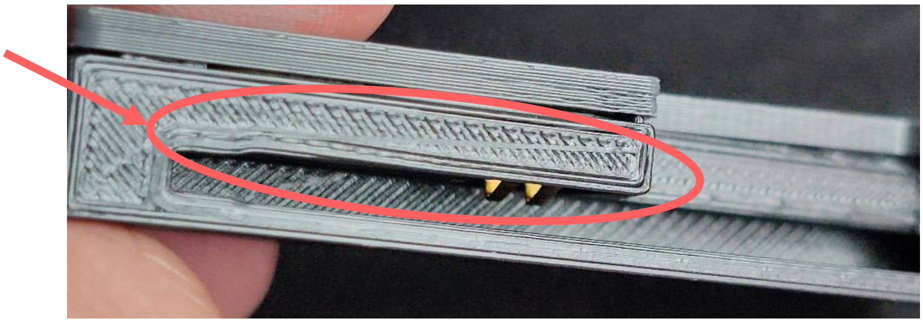


Figure 4.13 Changed thickness (top part).

4.9 Different designs (Prototype variant)

After designing many different versions of the chargers. It was necessary to choose the best design for the first batch. The second version will be redesigned to make sure it is ready for mass production. In total there are designed four different versions. For the first and second version see figure 4.14, for the third version see figure 4.15, and for the final and fourth version see figure 4.16.

Figure 4.14 First and second version of the charger

Figure 4.15 New design, third version renders

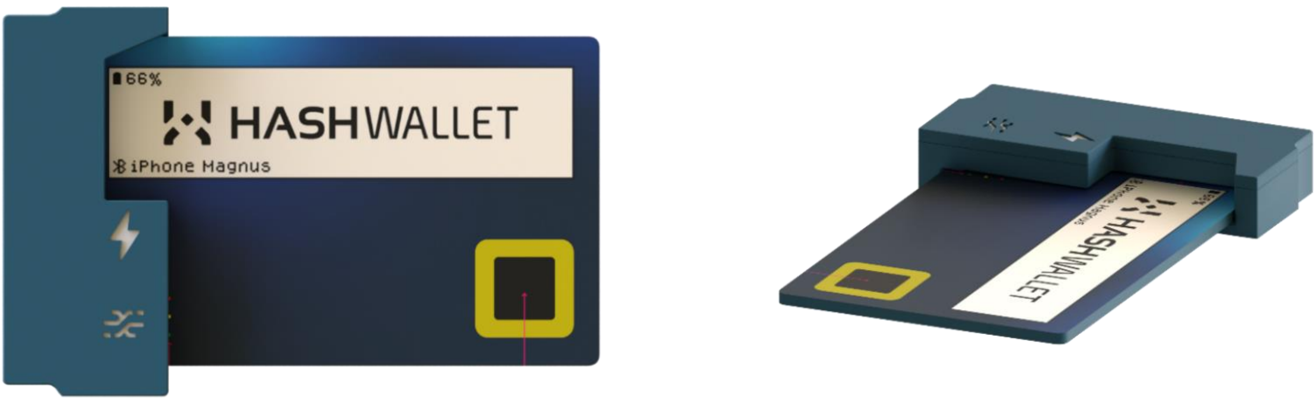


Figure 4.16 New design, fourth version renders

4.10 Choosing design

The project group has decided that the more compact design from figure 4.16 was the best solution for the first version. This concept version was as compact as it could get with the current charging board, the card slides in and out easily, the protype did function well and the LED indication lights where easily visible (see figure 4.17).

Figure 4.17 render chosen design

4.10 Final version for SLA and SLS production

For the SLS an SLA printing part there where made some small changes to the model. These updates where mainly focused on aesthetics and the USB-C connection port (see figure 4.18). For aesthetics there was added a card insert icon and card indication line. So that consumers know exactly how to orientate and place the card within the charger. Besides that, some slight adjustments have been made to the USB-C port to ensure that it fits securely.

The charger will also be painted black, therefor the 3D designs have been changed to a darker grey/black colour. This makes validating process more efficient. The final version is rendered below (see figure 4.19).

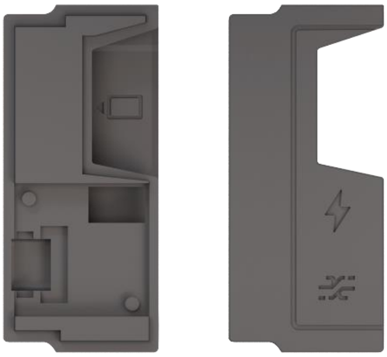


Figure 4.18 Charger chassis 3D render

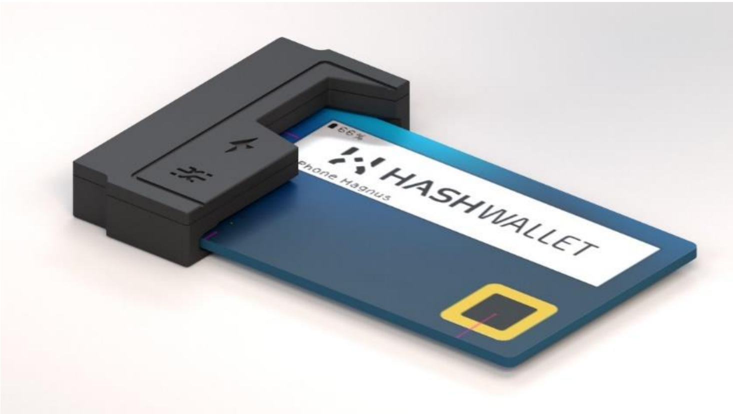


Figure 4.19 Final Renders

4.11 3D workflow

The 3D models are designed within 3Ds max (see figure 4.20) and will be converted and edited to Fusion 360 to make the final production design.

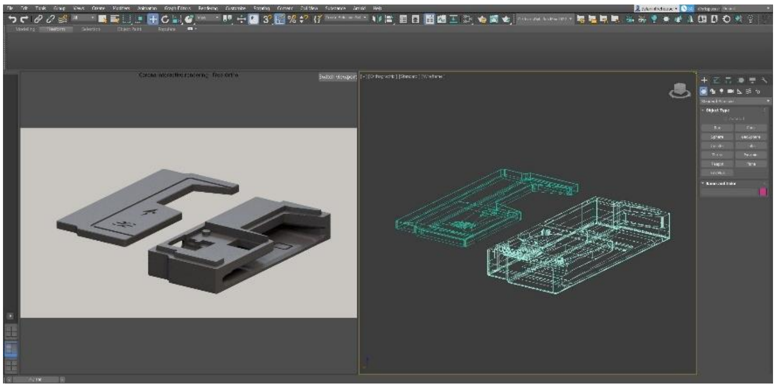


Figure 4.20 3Ds max workflow

4.12 Setting up new SLA printer

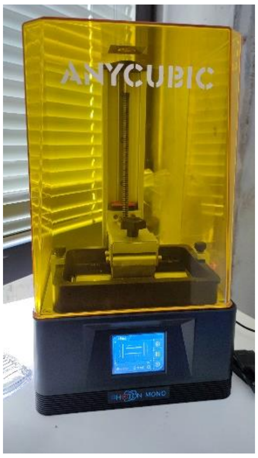


Figure 4.21 SLA printer office

To create better detailed protypes eSignus has invested in an SLA 3D printer. This printer is installed on the 3rd of November in the office of Las Palmas de Gran Canaria. It is placed in a separate well-ventilated room so that it does not distract anyone in the office. Besides this resin fumes are quite unpleasant and dangerous to work with. Therefor it was advised to place it in a separate well-ventilated room. To maintain a secure and safe work environment there has been invested in some safety gear. Like safety glasses, gloves, plastic containers, tweezers, and face masks.

While working with the SLA printer it is recommended to fallow the fallowing process steps. These are created to make sure everyone knows how to operate the printer safely (see table 4.1 and figure 4.22).

Table 4.1 (M)SLA 3D printer operational steps

Steps	Activity	Safety requirements
1	Refill the resin in the vat	Use safety gloves and mask
2	Close the UV protection cover on the resin vat	Use safety gloves
3	Turn on SLA printer and choose correct file	-
4	Wait until print is finished	-
5	Remove the UV protection cover	Use safety gloves and mask
6	Remove build plate from printer	Use safety gloves, mask, and goggles
7	Spray isopropyl 95/99% on the print with the spray bottle, above the large container	Use safety gloves, mask and goggles
8	Remove all supports from the print, above the large translucent container	Use safety gloves, mask, and goggles
9	Remove the print with the slicer in the smaller container, that contains also isopropyl.	Use safety gloves, mask and goggles
10	Clean the build plate first with the spray bottle and scraper, above the large translucent container.	Use safety gloves, mask, and goggles
11	Place the clean build plate in the drying reck	Use safety gloves, mask, and goggles
12	Place the UV protection cover back on the printer	Use safety gloves, mask, and goggles
13	Take a small brush and remove the last over resin from the prints (max 3 min).	Use safety gloves, mask, and goggles
14	After cleaning the prints let them dry for a few minutes on the drying reck.	Use safety gloves, mask, and goggles
15	After drying place, the prints in the UV curing station	Use safety gloves and mask
16	Turn on the UV curing station and make sure that all sides are cured evenly	Use safety gloves and mask
17	After curing take prints out and they are ready to be used.	-
18	Clean the workstation so it is ready for the next print	Use safety gloves and mask

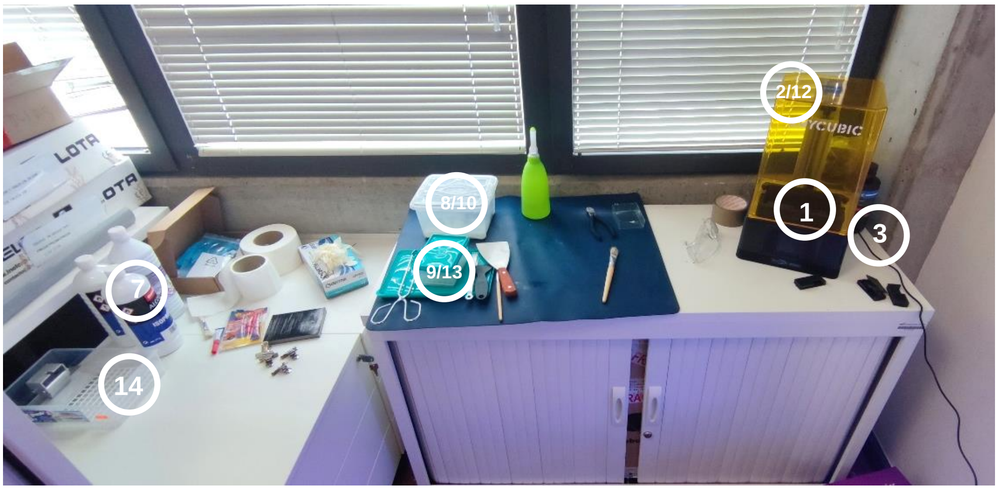


Figure 4.22 Workspace SLA printer

4.13 SLA printing process

In figure 4.23 and figure 4.24 all SLA printing steps are displayed as a process map and with additional images that can support the process. With the safety guidelines from table 4.1 and by fallowing the process map, you are able to safely operate the (M)SLA printer. Please keep in mind to wear gloves, a mask and goggles while working with the resin.

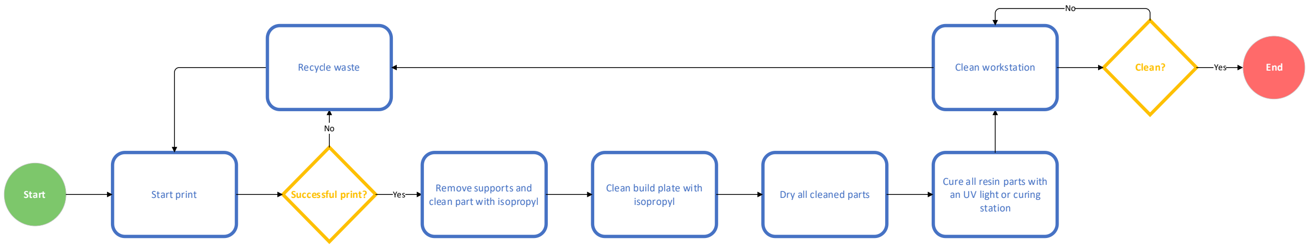


Figure 4.23 SLA printing process

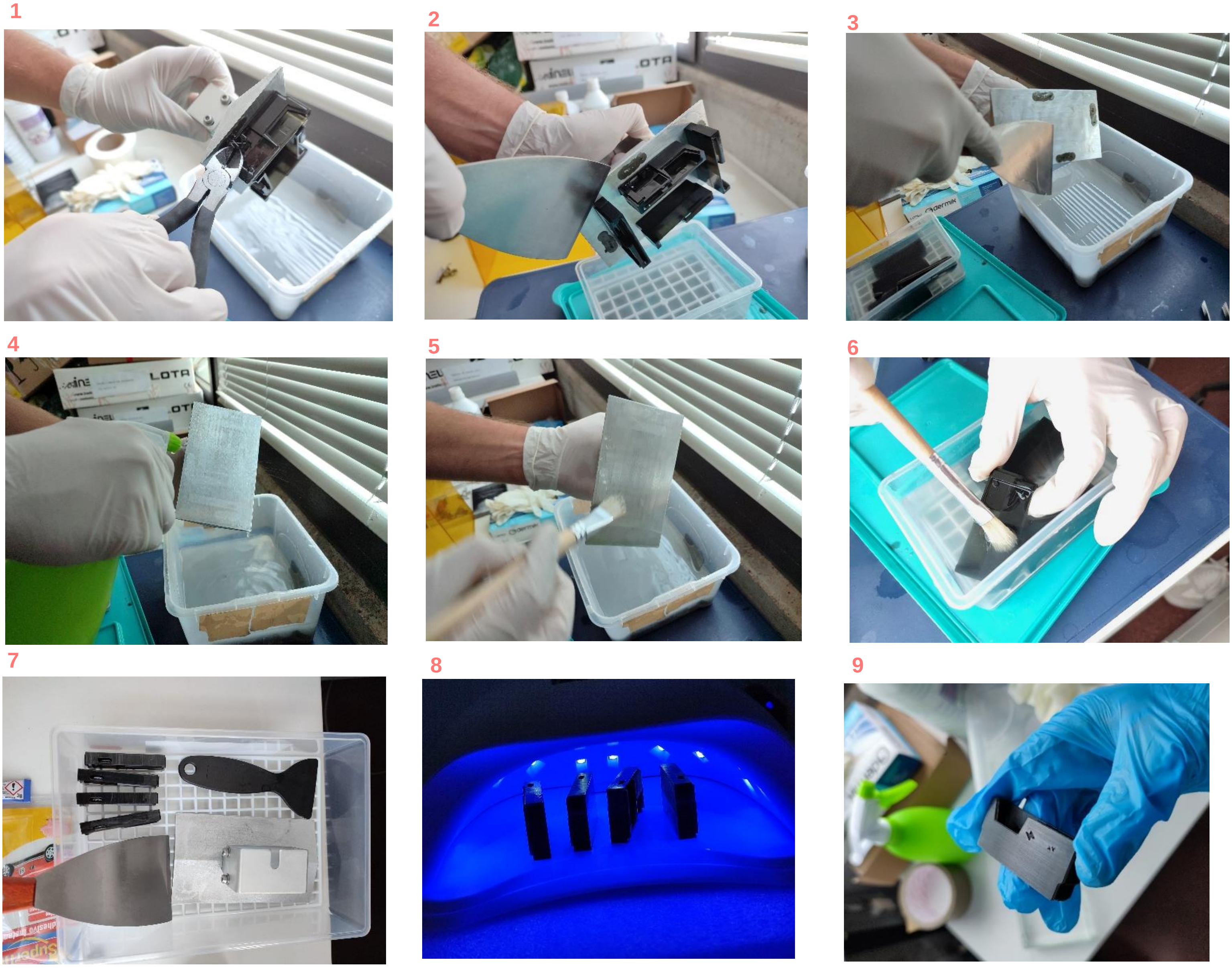


Figure 4.24 Process steps with images SLA print

Date: 12-01-2022
Author: DD Dreyer Varsics

4.14 Gluing process

In figure 4.25 and 4.26 all gluing steps are displayed with a process map and additional images. Please keep in mind to wear gloves while working with strong glue.

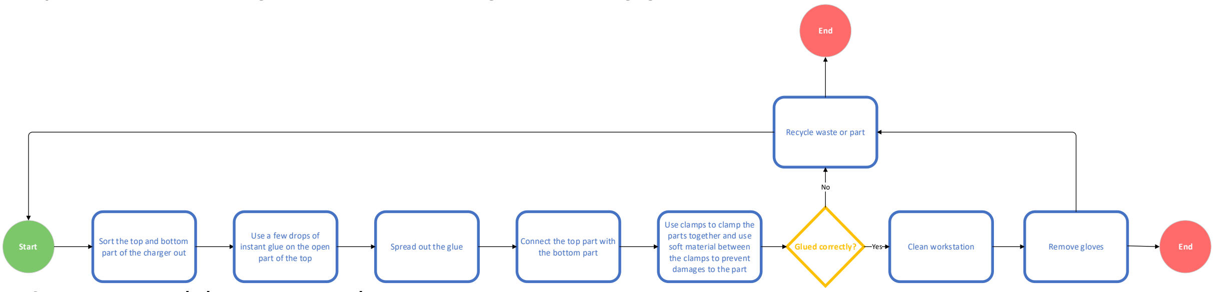


Figure 4.25 Process gluing protype charger

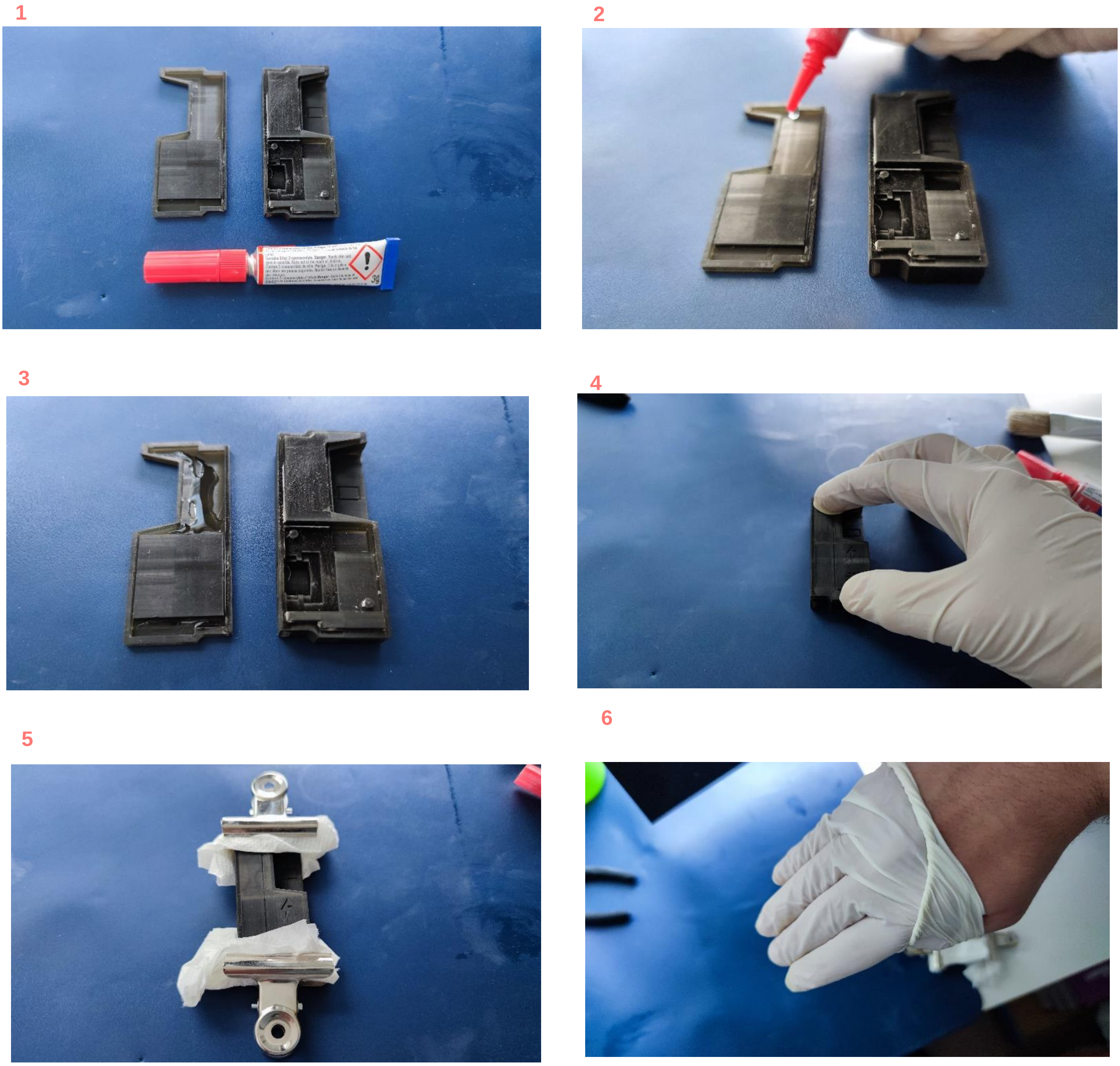


Figure 4.26 Process steps with images gluing top part to bottom part

4.15 (M)SLA 3D printed prototypes

The resin prototypes came a long way from the first print. At the start prints had some defects, because working with an SLA printer is quite different from working with an FDM printer. After two days the prints became better by making some slight adjustments to the printing position and switching form slicing software. Alexis helped the project team by giving some feedback and advice about slicing software's. Prints improved, after switching to a different slicing software (Lychee slicer 3). With this software it was easy to move the printing supports away from the main print (see figure 4.27). This resulted in less cleanup work and better print quality.

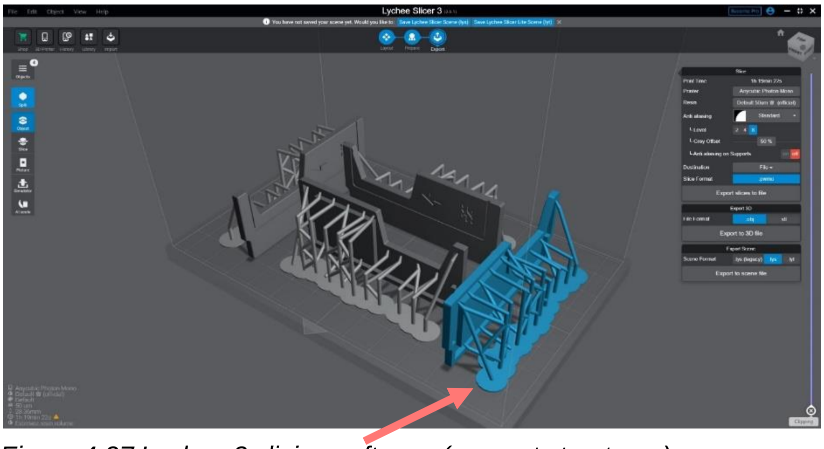


Figure 4.27 Lychee 3 slicing software (support structures)

Difference early and updated prints:

The difference between the first and final prints are quite significant (see figure 4.28). At first the prints where far from perfect and after a week of trial and error, the prints had improved. There were added some small appearance and minor dimension changes to the model after the prototype prints had improved.

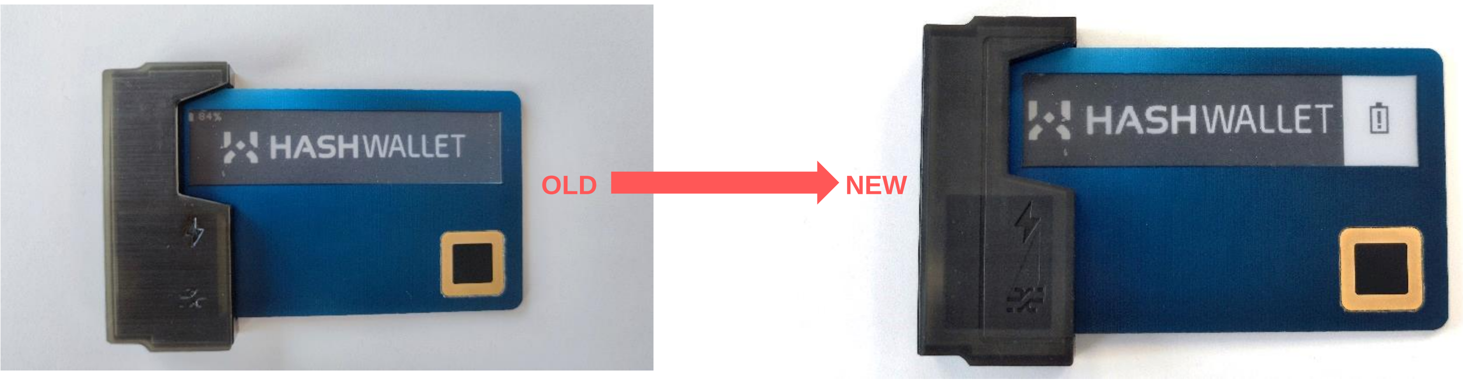


Figure 4.28 Early version resin print – updated version resin print

Painting the prototypes:

Resin is translucent from itself as you can see from figure 4.28. To meet client expectations a black paint layer was applied by spraying mate black colored paint at the prototype. See figure 4.29 for the final result.

Figure 4.29 painting the chargers

4.16 Prototype test run

After printing many prototypes, the design was ready to be tested and verified. In figure 4.30 you see the prototype charging the HASHWallet. This meant that the prototype was fully operational and could be used at certain events and within the eSignus team. After this step about ten prototypes will be created for the team and event use cases. Besides that, one prototype will be shipped to the packaging designer and manufacturer. This company will adjust the packaging to fit the charger within the packaging of the HASHWallet. After this step the outer dimensions of the first batch version cannot be changed anymore. Smaller internal changes can be made to make to improve the first batch version of the charger.

Figure 4.30 Testing the prototype charger

Additional images of the prototype:

Bellow there have been added some extra references of the final protype charger (see figure 4.31).

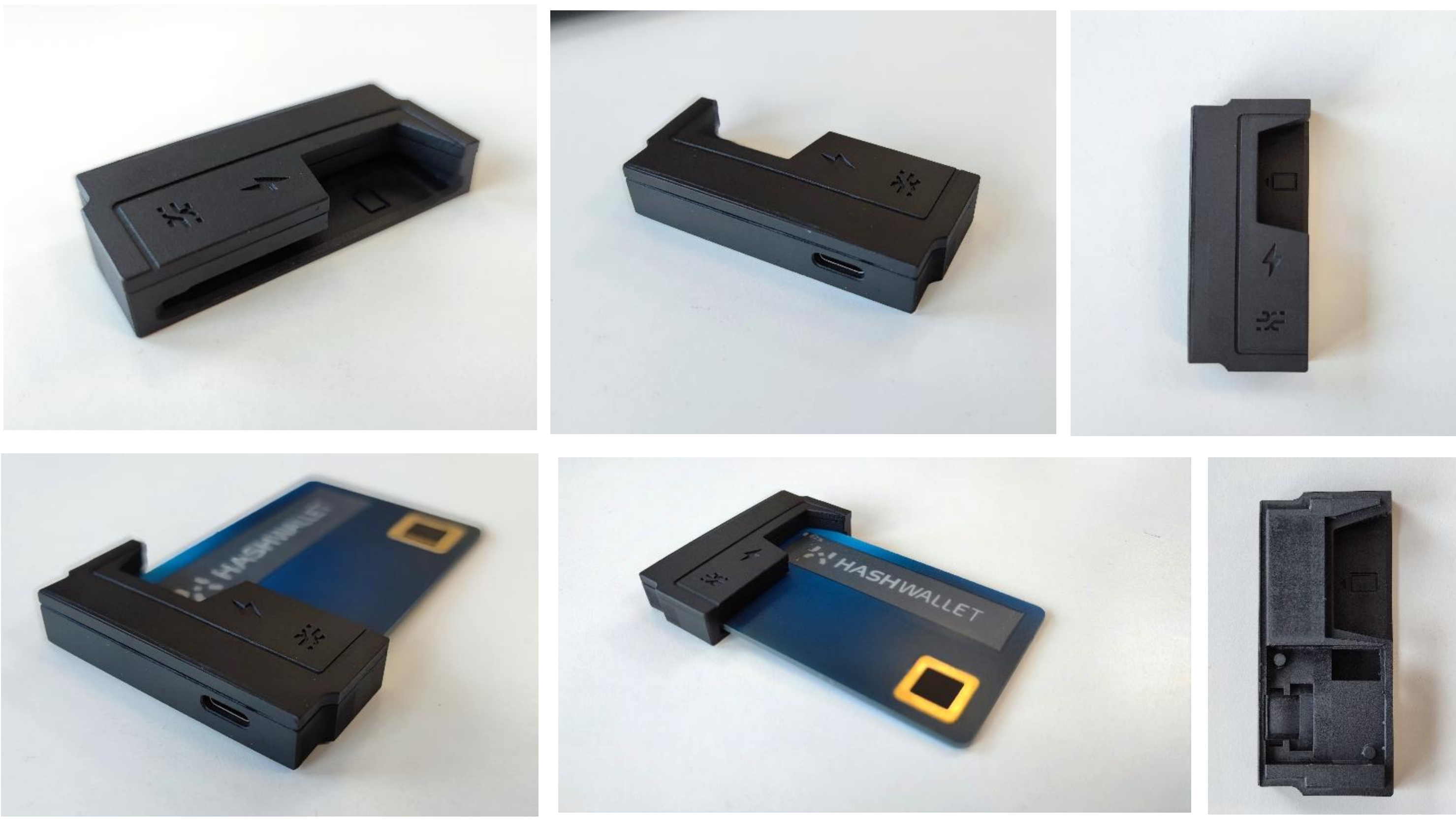


Figure 4.31 Additional images of the prototype charger

4.17 Final charger design

The final charger designs are displayed in figure 4.32. The design operates fully with the newer versions of the HASHWallet. See the validating process in the attachment, paragraph 4.18. Only small changes have been made to the design, like the connection part of the top see red circle in figure 4.32. This change to the design makes the part sturdier.

Figure 4.32 Final first batch 3D charger designs

4.18 Validating final design – Key performance indicators check (KPI´s)

The project team validated the final prototype in this paragraph, see table table 4.2 for the requirements with validation. In figure 4.33 you see the charger with the USB-C port and the final test of the charger. The HASHWallet is charging, and the indication lights are visible while charging. Please read table 4.2 for the full verification check

Table 4.2 Validation of the requirements

Check	Functional requirements of both chargers	Design KPI´s	Verification check
✓	The charger will not damage the hardware wallet	Minimal friction (only sides and connecter point)	The charger has minimal friction and there are no marks when using the charger often. This is tested by the team.
✓	The max weight of the charger is less then	<50 gram	The charger weights around 30 grams with the charging board and after painting.
✓	Minimal operational temperature	0-40 °C	The charger does not get hot while charging the HASHWallet.
✓	The charger must have a USB connector	Type C	The charger has an USB-C port
✓	The dimensions of the charger must fit in the current packaging dimensions	85x 54 x 15 mm (L*W*H)	The charger fits in the current designed packaging.

Check	Operational requirements of the first batch charger	Verification check
✓	The charger must be easy to use	The charger is easy to use and has markings on it to guide the user.
✓	The charger must work with the new HASHWallet design	The prototype charges and fully functions with the HASHWallet.
✓	The charger will not damage the hardware wallets	The charger does not damage the HASHWalet under normal use.
✓	The charger is portable and easy to carry	The charger is very compact ant easy to carry around.
✓	The battery health is not influenced by the charging method (under normal conditions)	The battery charges normally, no operational error detected while testing for a week.
✓	The dimensions of the charger must fit in the current packaging dimensions	The charger fits within the maximal set packaging dimensions.
✓	The charger does offer minimal to no wear on the HASHWallet	The charger does offer minimal friction to the HASHWallet. Only the sides tach the hardware wallet. Top bottom is lifted to prevent scratching the device.
✓	The charger must charge faster than using the wireless charging method	The charger offers current flow to the HASHWallet what results in better and more reliable charging over wirelessly charging the device.
✓	The charger must be functional while charging	The charger can be used while charging the device, screen and fingerprint reader are free from obstruction.
✓	The LED indication lights are not obstructed while charging	The LED indication lights are clearly visible while charging the device.

Figure 4.33 Testing and validation of the charger

4.19 Prototype progress

Many prototypes were created for the first version of the charger. These prototypes where created with different types of printers and materials. Please see the whole prototyping process in figure 4.32.

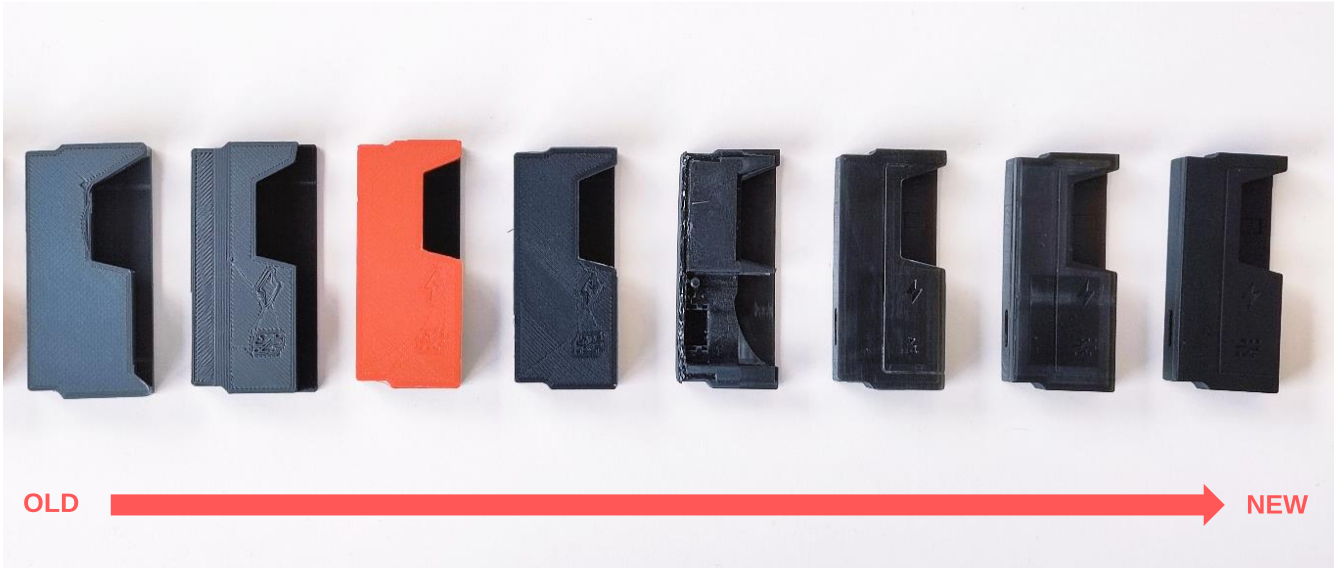


Figure 4.32 prototype progress

5. Optimise phase

5.1 Choosing optimal design for mass manufacturing

As noted earlier in the research phase of the project it was clear that the final version of the charger design needed to be optimised for injection moulding. This production technique will be the most optimised production method on large scale. The charger needs to be designed with the manufacturing guidelines to keep the custom mould cost down as much as possible. Therefor it was necessary to make fundamental changes to the design. The part needed to exist of minimal three pieces to avoid any undercuts. Two different versions where designed and 3D printed to test which of the two versions would be optimised to all design for manufacturing guidelines.

First version:

The first option where the USB-C port is shared with the top part is shown in figure 5.1. The advantages are that this option is easy to assemble. Besides that, the seam lines are straight around the charger. The disadvantage is that only one colour can be used for the main chassis of the charger.

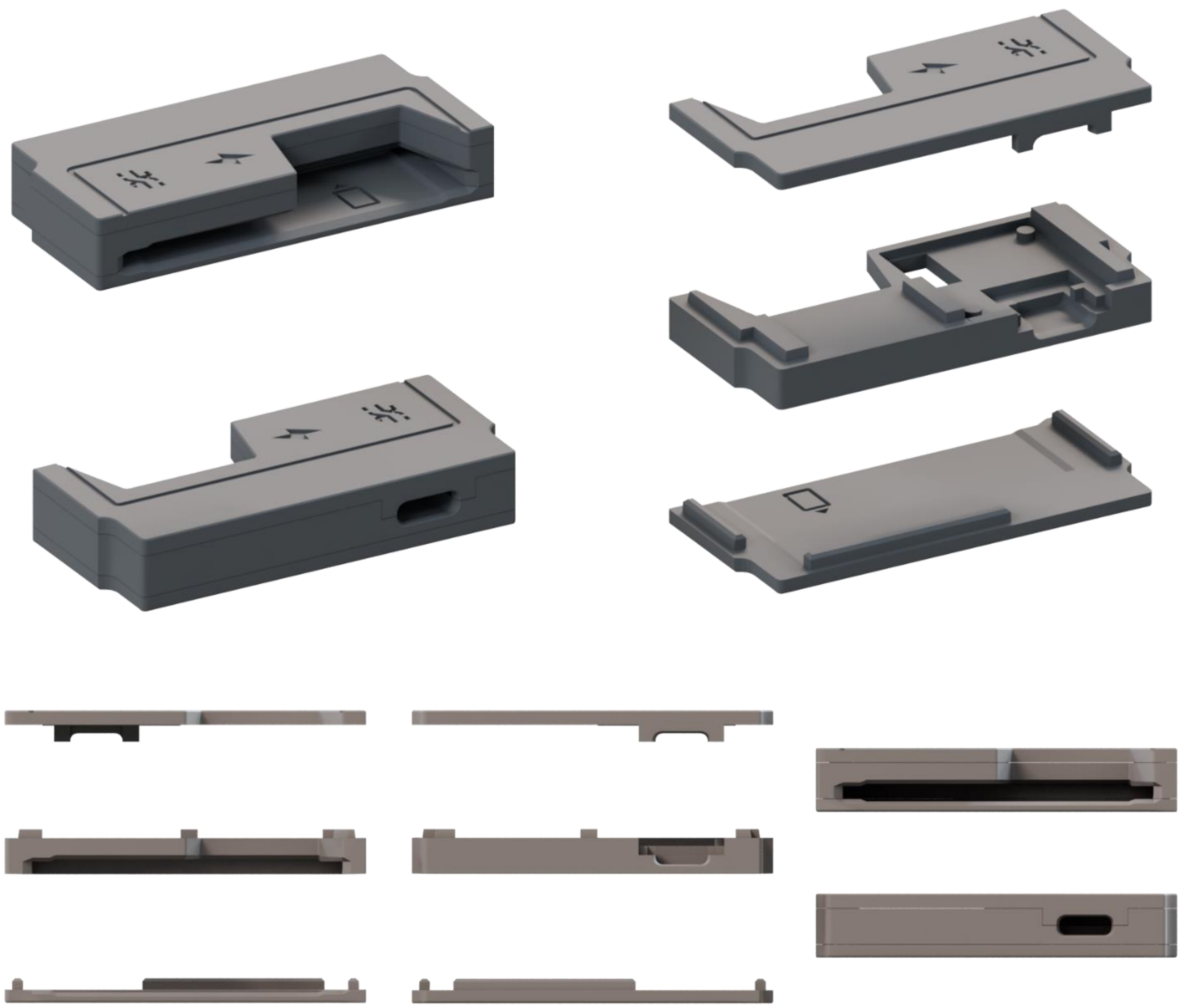


Figure 5.1 First version for the mass production charger chassis

Second version:

The second option has the USB-C port split in half and shared with the bottom part of the charger (see figure 5.2). The advantage with this method is that the top part can have a different colour from the bottom part of the charger as seen in the figures (5.2). The disadvantage is that the seam line is not fully aligned with the charger. Because there needs to be a slight angle placed to mitigate the minimum thickness of the charging board.

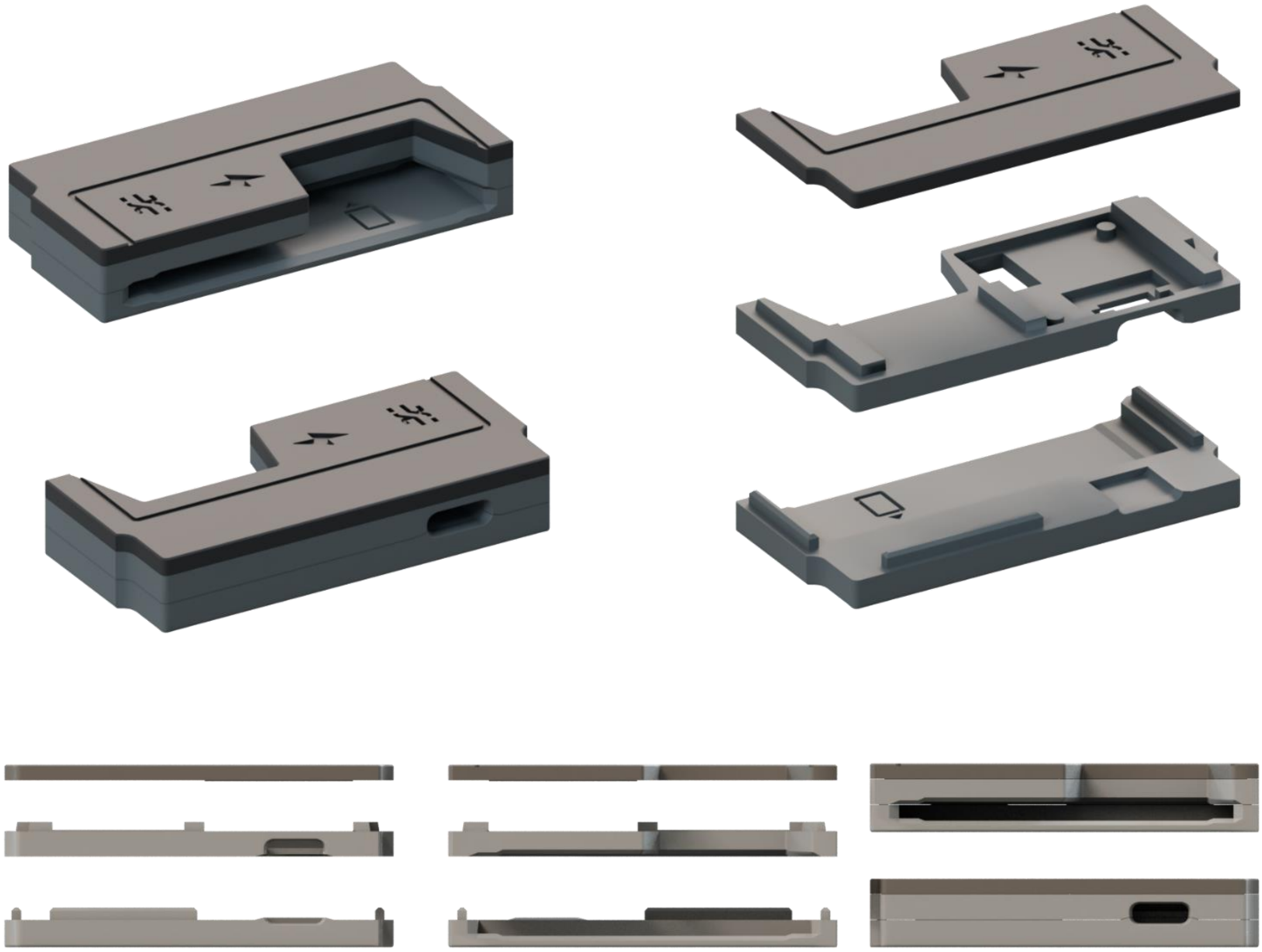


Figure 5.2 Second version for the mass production charger chassis

5.2 First 3D printed protypes for the mass production version

In this paragraph the two different versions have been 3D printed and tested with the newer manufactured HASHWallets. The newer HASHWallets became a bit thinner, therefor the designs needed to change a bit, regarding the card thickness and other factors that have changed. These changes will be incorporated in the final mass manufacturing design. Please see figure 5.3 for the two different prototype designs.

Figure 5.3 3D printed prototype chargers (3 pieces)

5.3 Redesigning the charger
For the redesign of the charger, it is recommended to have uniform walls. Besides that, the charger needs to be designed with design for manufacturing guidelines. These guidelines are described in chapter three.

5.4 Design in fusion 360
The final version of the charger has been made in fusion 360, with this software it was possible to design the charger with the necessary design with manufacturing guidelines that were determined in the analyse phase. In figure 5.4, you see the designed version in fusion 360.

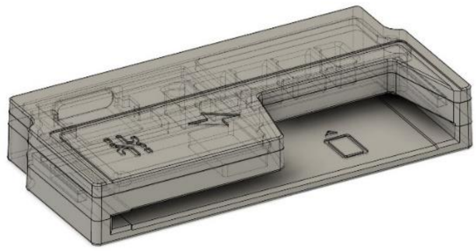


Figure 5.4 Final mass production HASHWallet charger

5.4 Testing final prototype:
In figure 5.5 you see the prototype charging the HASHWallet. This meant that the prototype was fully operational and could be manufactured. Still there is much room for improvement regarding the manufacturing side of the design. The middle part of the charger is too thin. This can be resolved to choose a different design where the top part is integrated within the middle part like in figure 5.1.

Figure 5.5 Final mass production HASHWallet prototype

5.5 Final visualisations
In figure 5.6 you are able to see the final 3D visualisations of the charger. The visualisations are created within 3ds max.

Figure 5.6 Final HASHWallet charger 3D visualisations

5.6 Testing final prototype:
The project team validated the final prototype in this paragraph, see table table 5.1 for the requirements with validation.

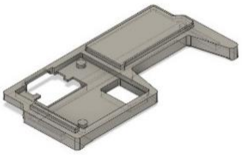
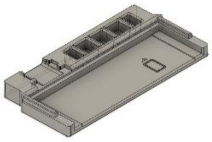
Table 5.1 Validation of the requirements

Check	Functional requirements of the final charger	Design Parameters and KPI´s	Verification check
✓	The charger will not damage the hardware wallet	Minimal friction (only sides and connecter point)	The charger has minimal friction and there are no marks when using the charger often. This is tested by the team.
✓	The max weight of the charger is	<50 gram	The charger weights around 25 grams with the charging board and after painting.
✓	Minimal operational temperature	0-40 °C	The charger does not get hot while charging the HASHWallet.
✓	The charger must have a USB connector	Type C	The charger has an USB-C port
✓	The dimensions of the charger must fit in the current packaging dimensions	85x 54 x 15 mm (L*W*H)	The charger is smaller than the maximum design parameters.
✓	Material of the charger	ABS	Material can be manufactured with ABS material.

Check	Operational requirements of the first batch charger	Verification check
✓	The charger must be easy to use	The charger is easy to use and has markings on it to guide the user.
✓	The charger must work with the new HASHWallet design	The prototype charges and fully functions with the HASHWallet.
✓	The charger will not damage the hardware wallets	The charger does not damage the HASHWalet under normal use.
✓	The charger is portable and easy to carry	The charger is very compact ant easy to carry around.
✓	The battery health is not influenced by the charging method (under normal conditions)	The battery charges normally, no operational error detected while testing for a week.
✓	The dimensions of the charger must fit in the current packaging dimensions	The charger fits within the maximal set packaging dimensions.
✓	The charger does offer minimal to no wear on the HASHWallet	The charger does offer minimal friction to the HASHWallet. Only the sides tach the hardware wallet. Top bottom is lifted to prevent scratching the device.
✓	The charger must charge faster than using the wireless charging method	The charger offers current flow to the HASHWallet what results in better and more reliable charging over wirelessly charging the device.
✓	The charger must be functional while charging	The charger can be used while charging the device, screen and fingerprint reader are free from obstruction.
✓	The LED indication lights are not obstructed while charging	The LED indication lights are clearly visible while charging the device.

6. Verify phase

6.1 Bill of materials:

Quantity	Parts	Dimensions	Manufacturing process	Cycle time (injection moulding)
1x Top part chassis		28.5x60x2.4mm (lxwxh)	- Injection moulding - Assembly - Gluing	- 17.7 seconds (please see injection molding simulations)
1x middle part chassis		28.5x60x4.9mm (lxwxh)	- Injection moulding - Assembly - Gluing	34.8 seconds (please see injection molding simulations)
1x Bottom part chassis		28.5x60x5.7mm (lxwxh)	- Injection moulding - Assembly - Gluing	48 Seconds (please see injection molding simulations)

6.2 Injection mould

Mould part 1
In figure 6.1 the mould of part 1 is visualised.

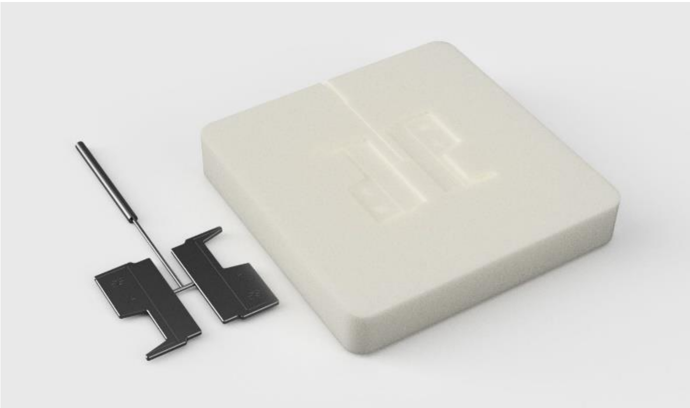


Figure 6.1 Mould design part 1

Mould part 2
In figure 6.2 the mould of part 2 is visualised.

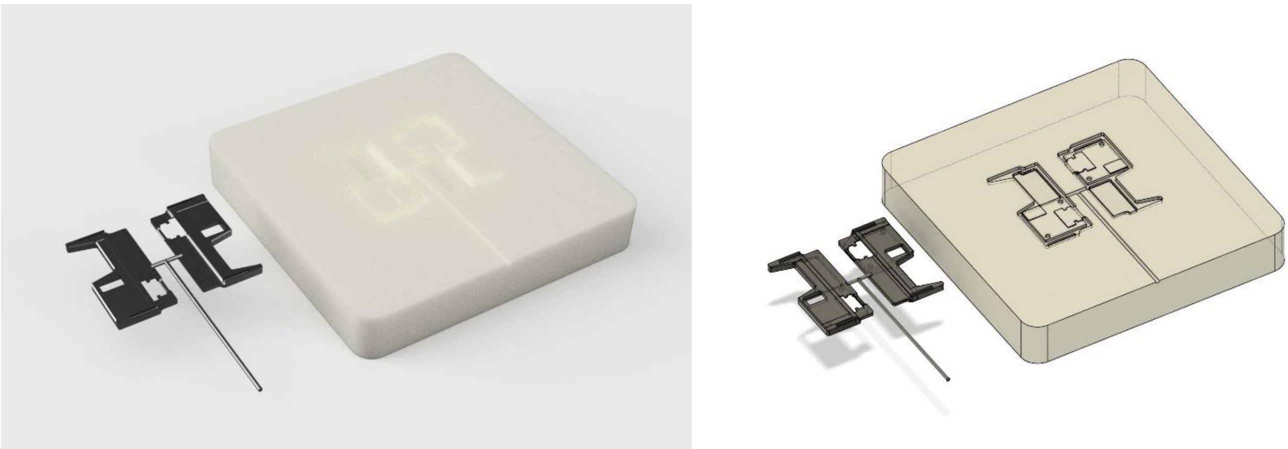


Figure 6.2 Mould design part 2

Mould part 3
In figure 6.3 the mould of part 3 is visualised.

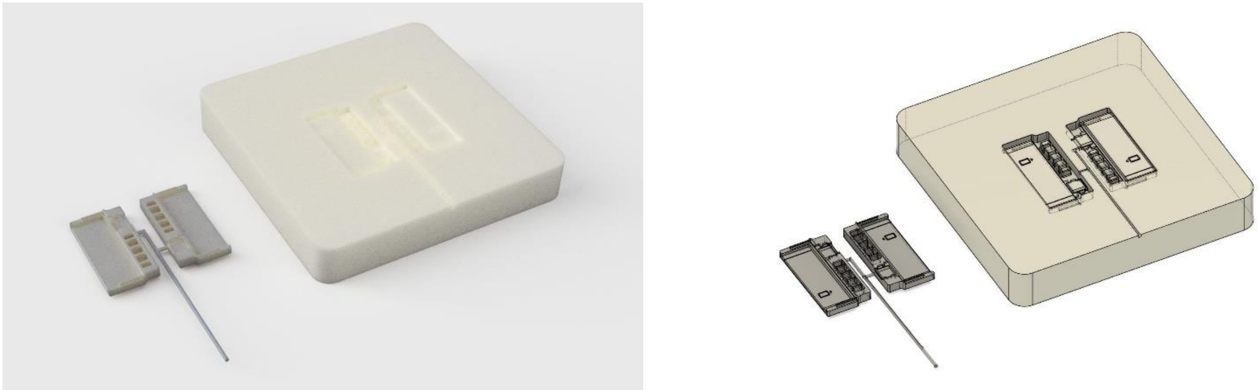


Figure 6.3 Mould design part 3

6.3 Manufacturing simulations

These simulations are created within Fusion 360. With the help of these simulations, it is easier to predict how the part will be injected moulded and what the strong and weakness are of each part. Besides that, it calculates the cycle time for each part. The simulations are run with ABS material

Part 1: Top part chassis
The fill confidence of the top part of the cassis is overall good. This means that the part is easy to fill with the utilization of injection moulding. There are some parts where there can occur minor difficulties please see figure 6.6 For the simulation outcome. The total injection moulding time will be 17.7 seconds, this time includes cooling and ejection time.

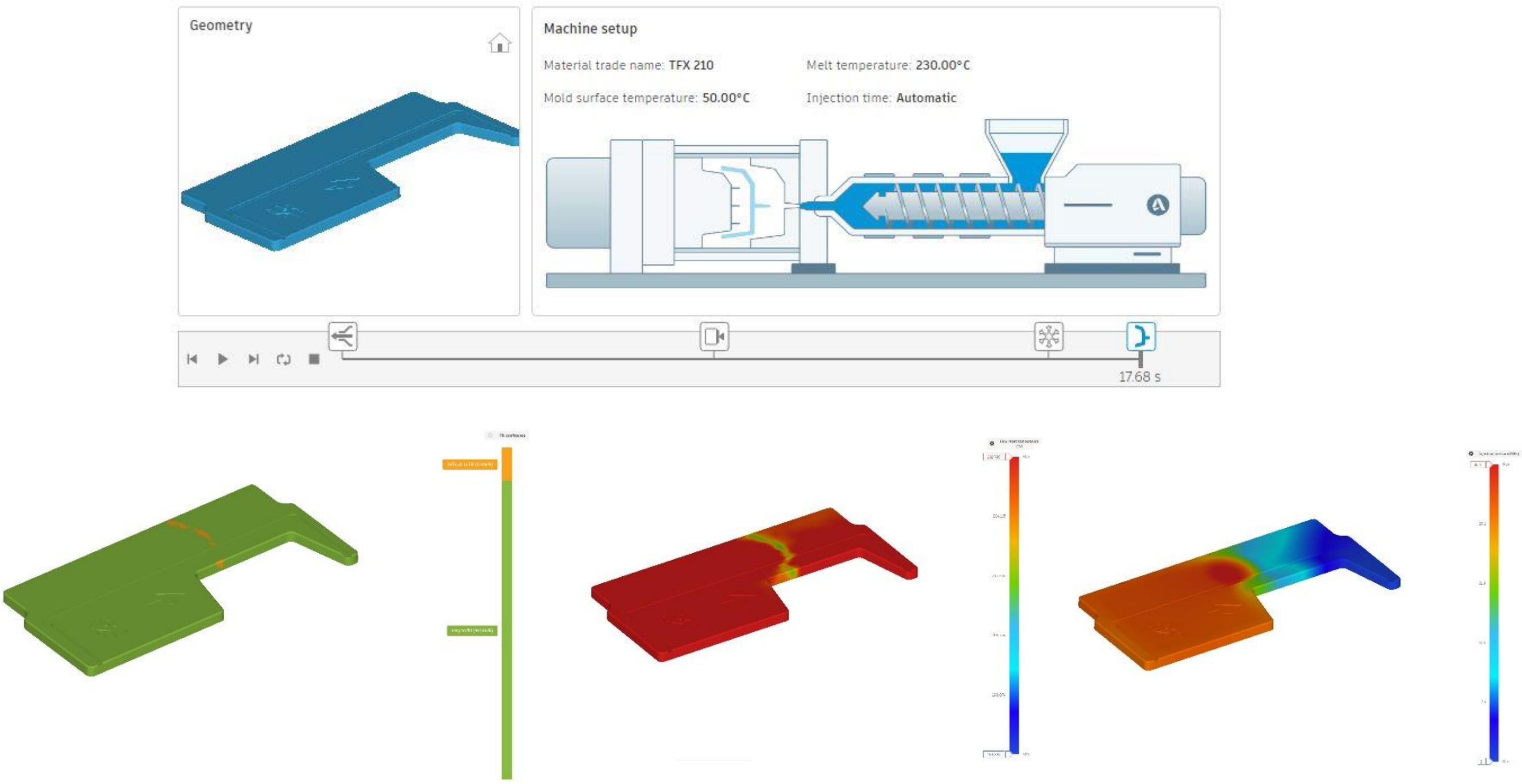


Figure 6.4 Injection mould simulations (part 1)

Part 2: Middle part chassis

The fill confidence of the middle part of the cassis is less than ideal. This means that there are some areas where the part cannot be correctly injected moulded. The issue is that the part is too thin to allow the flow to easily pass through the part. There are some parts where there can occur minor difficulties please see figure 6.5 for the simulation outcome. The total injection moulding time will be 34.8 seconds, this time includes cooling and ejection time.

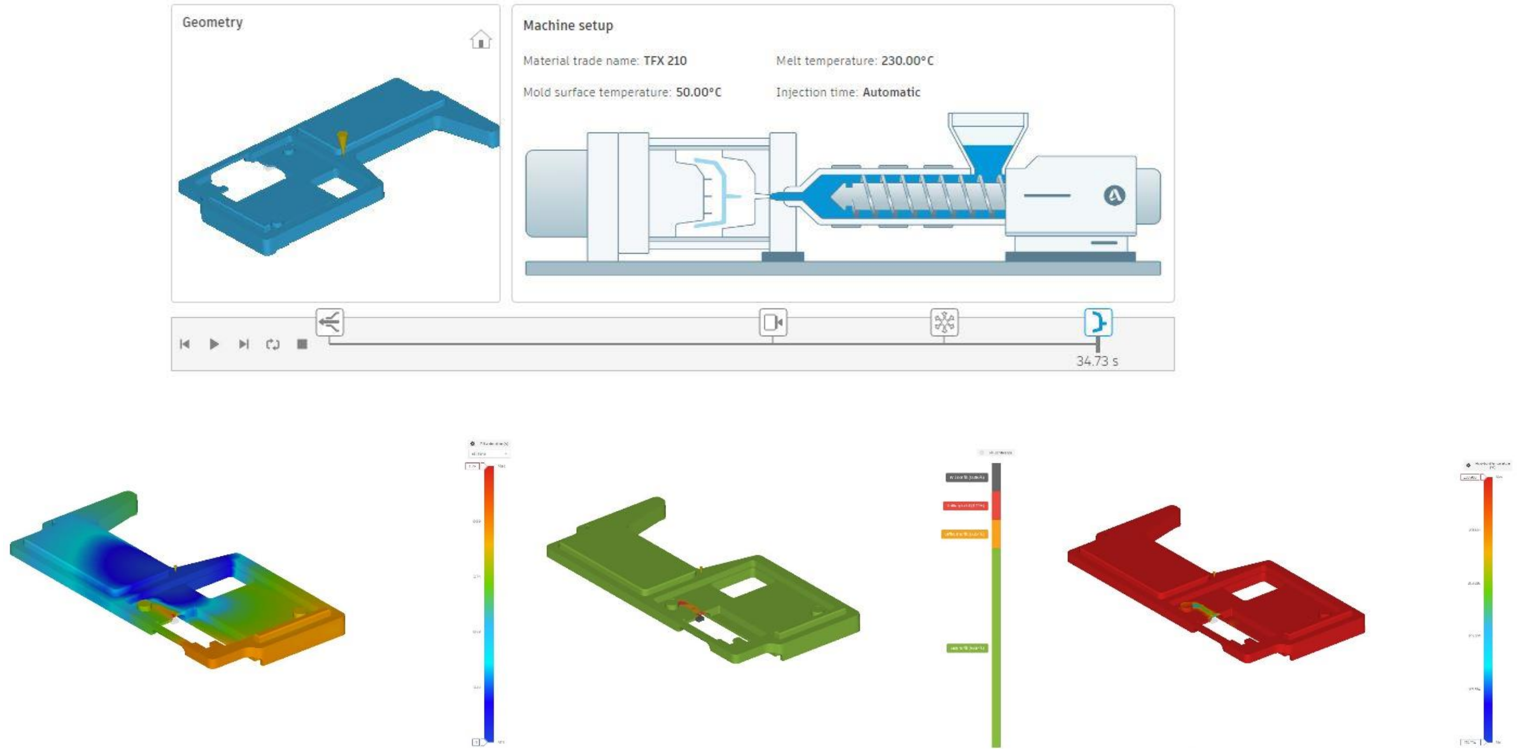


Figure 6.5 Injection mould simulations (part 2)

Part 3: Bottom part chassis

The fill confidence of the top bottom of the cassis is overall good. This means that the part is easy to fill with the utilization of injection moulding. Please see figure 6.6 the simulation results for the outcome. The total injection moulding time will be 17.7 seconds, this time includes cooling and ejection time.

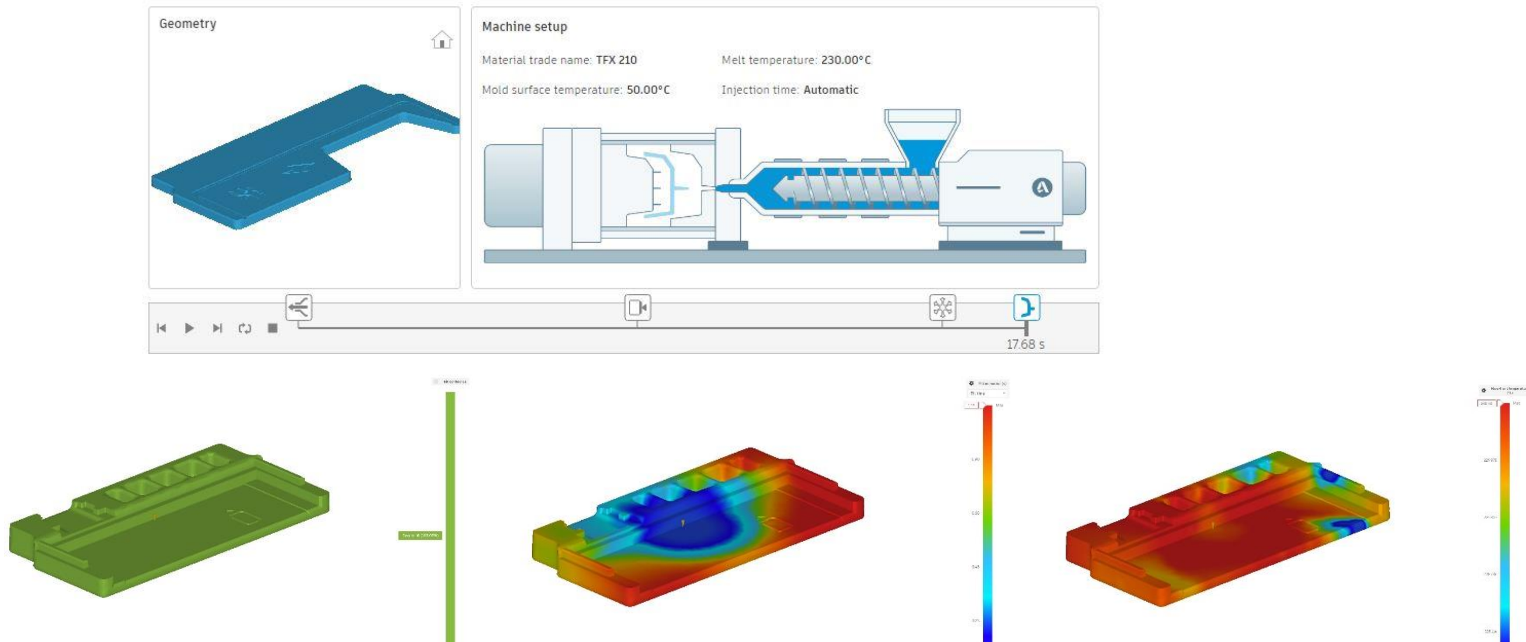
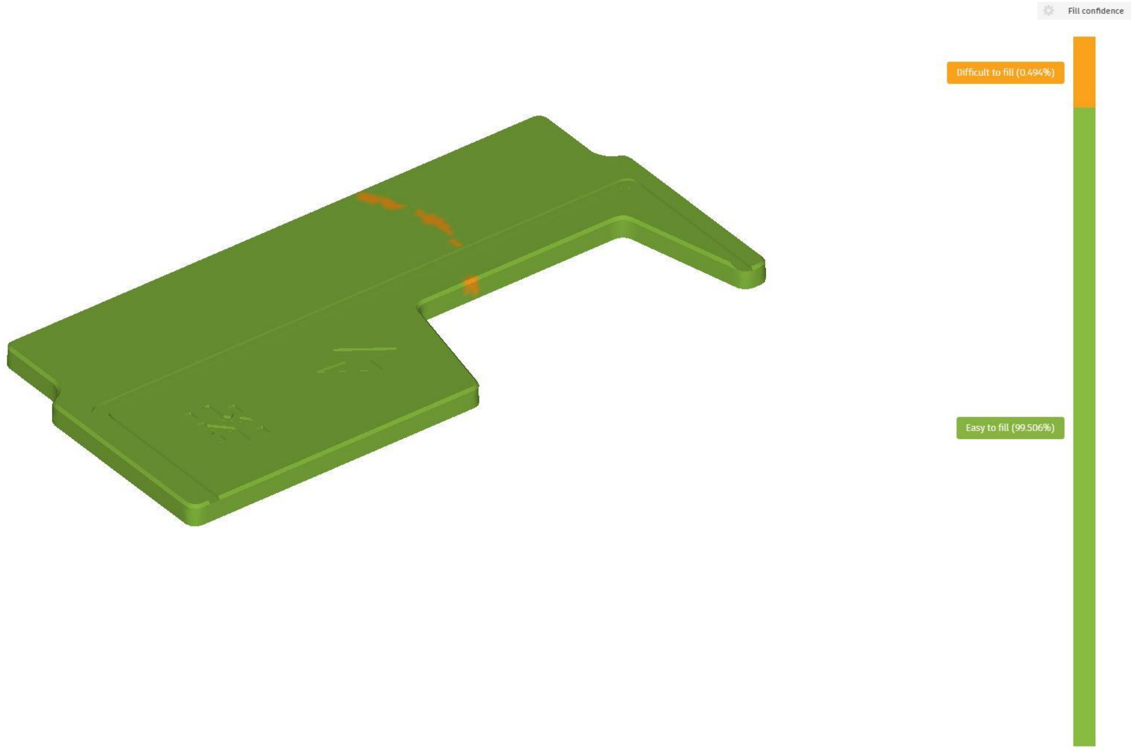
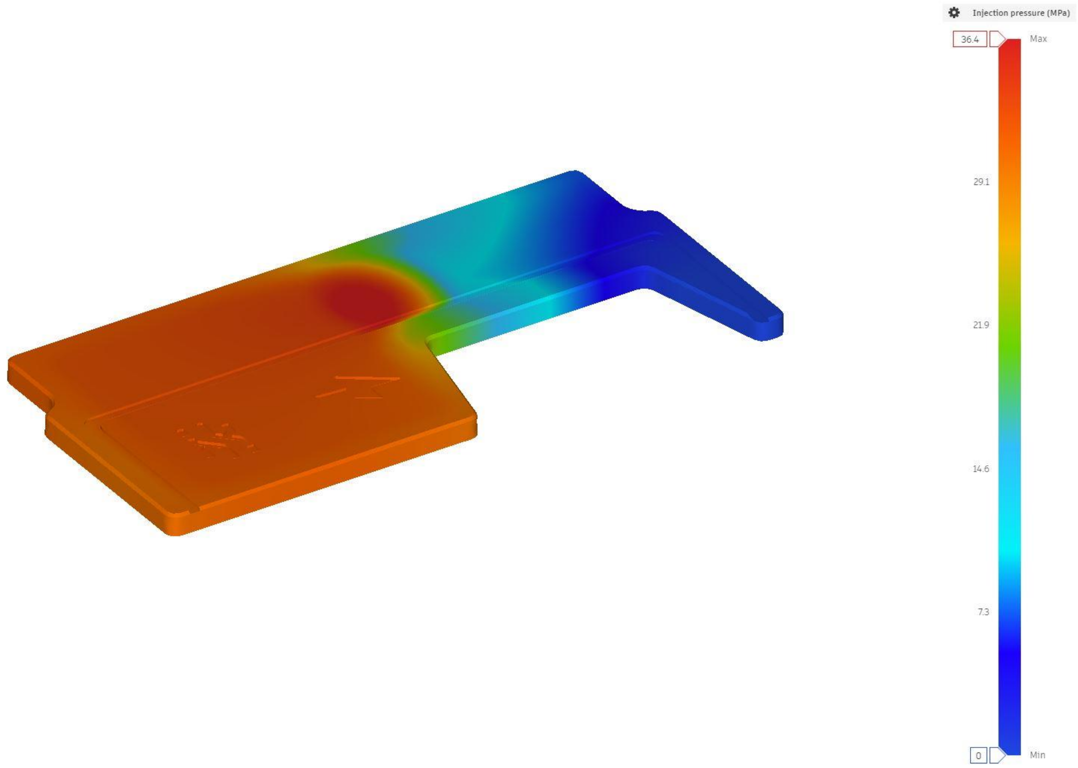


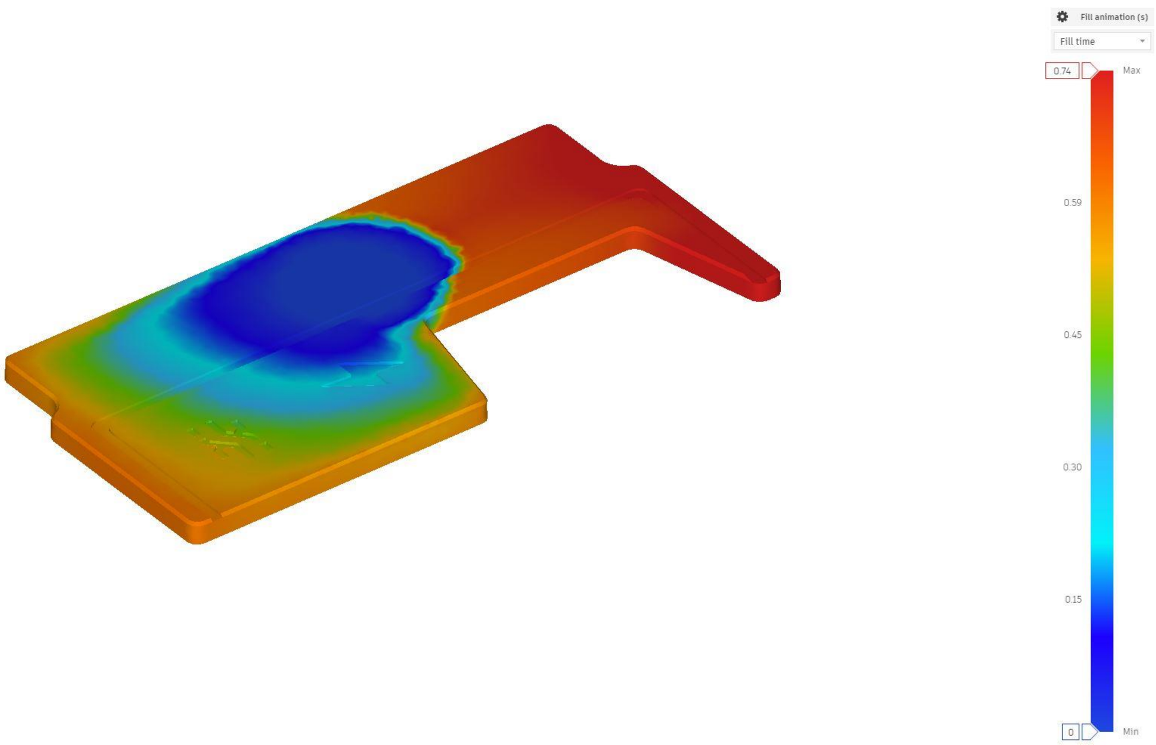
Figure 6.6 Injection mould simulations (part 3)

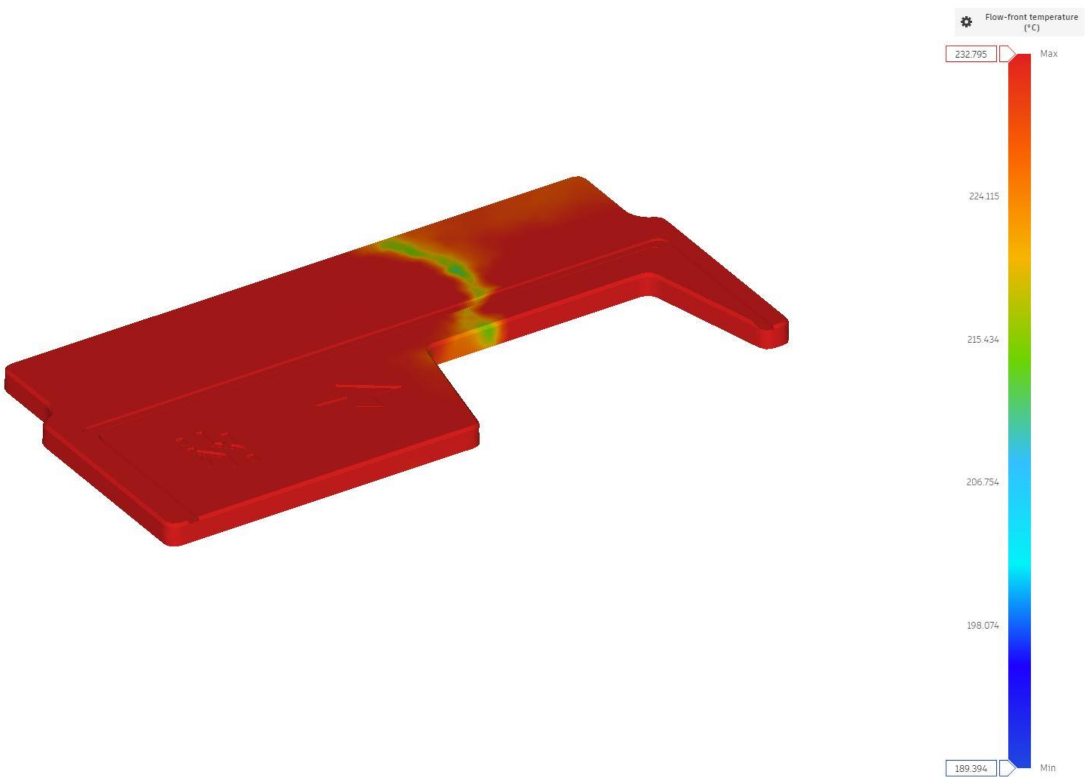
6.4 High quality injection moulding simulation images:

Part 1:

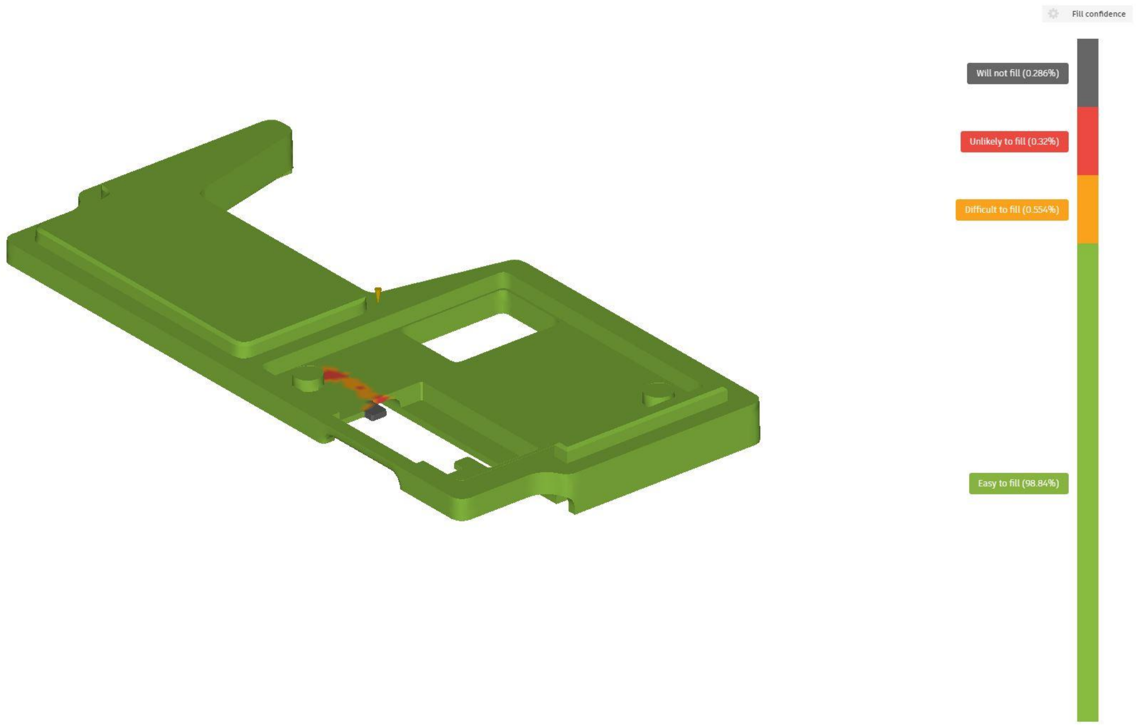


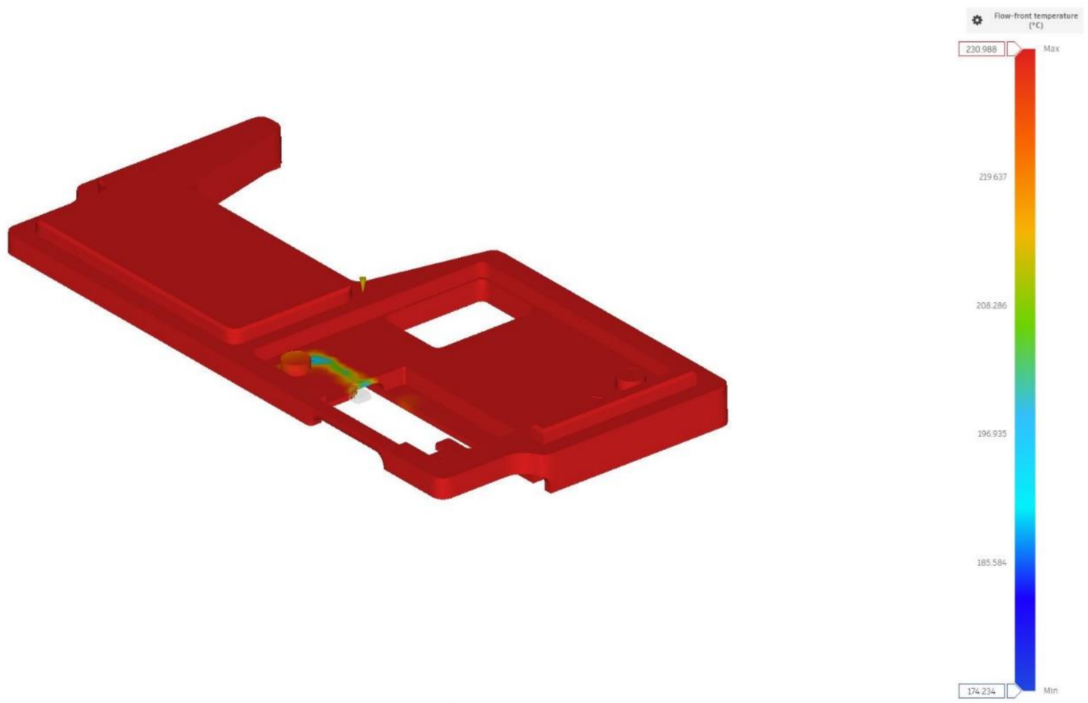


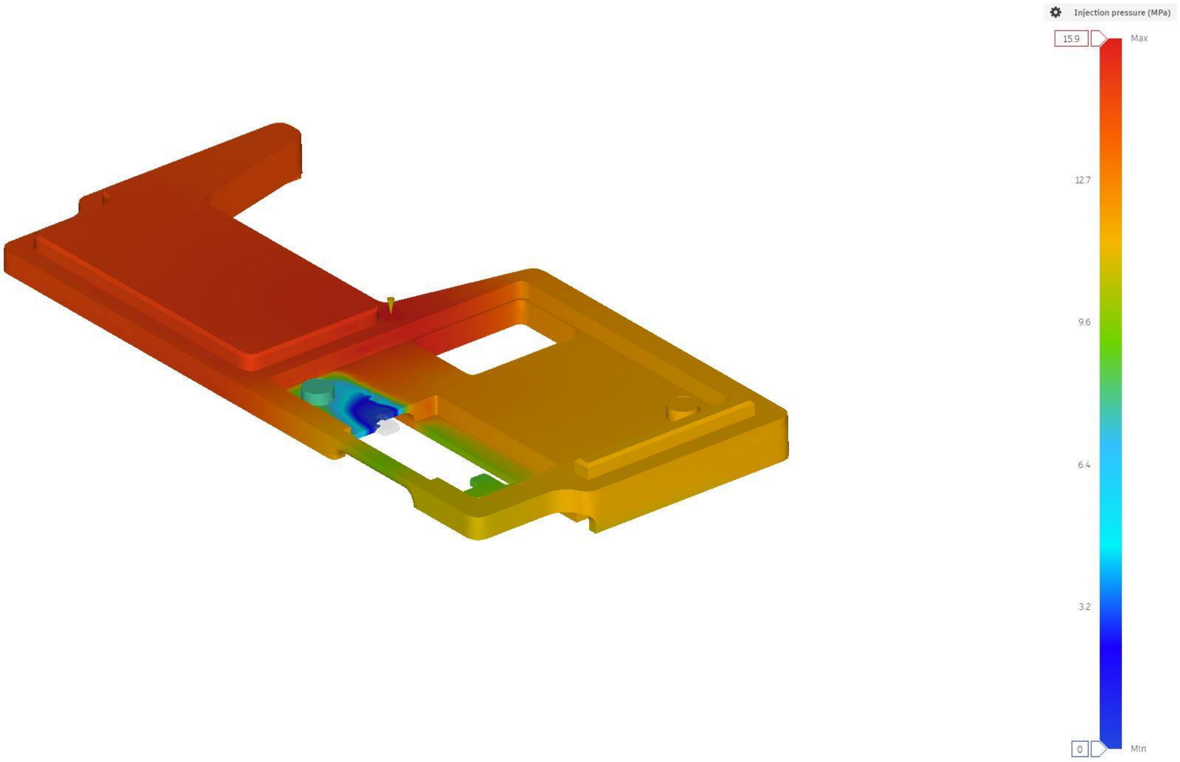

Fill animation (s)
Fill time
0.74
Max
0.59
0.45
0.30
0.15
0
Min

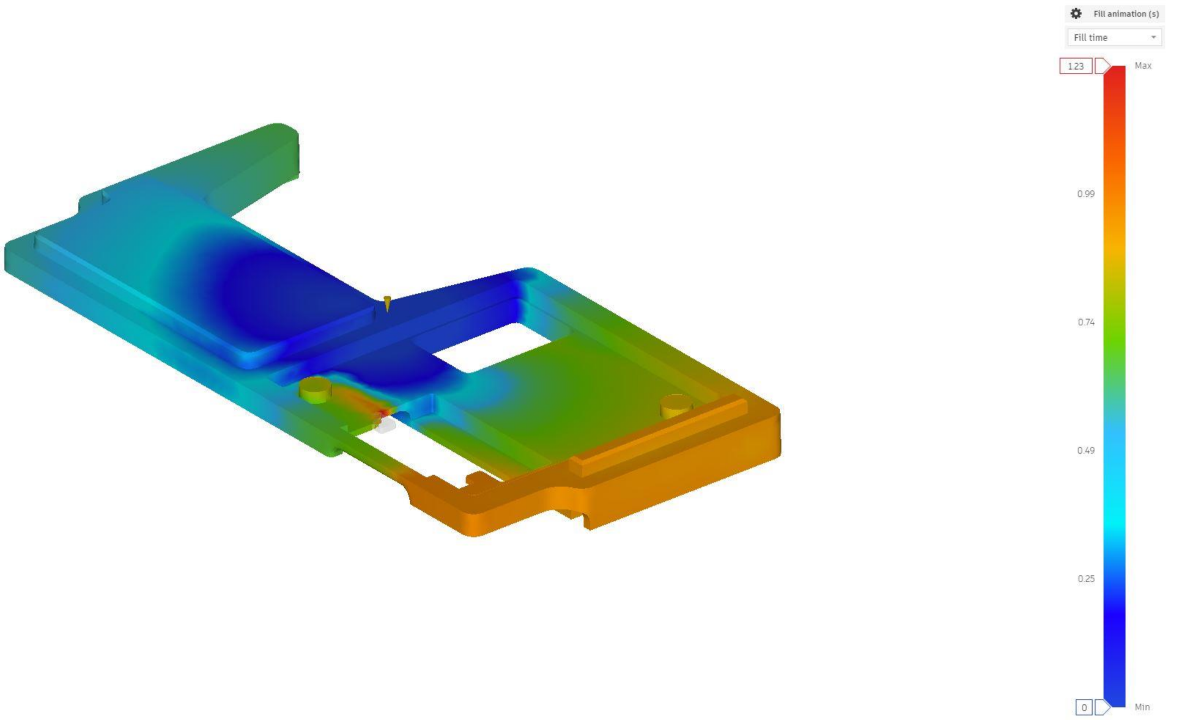

Flow-front temperature (°C)
232.795
Max
224.115
215.434
206.754
198.074
189.394
Min

Part 2:

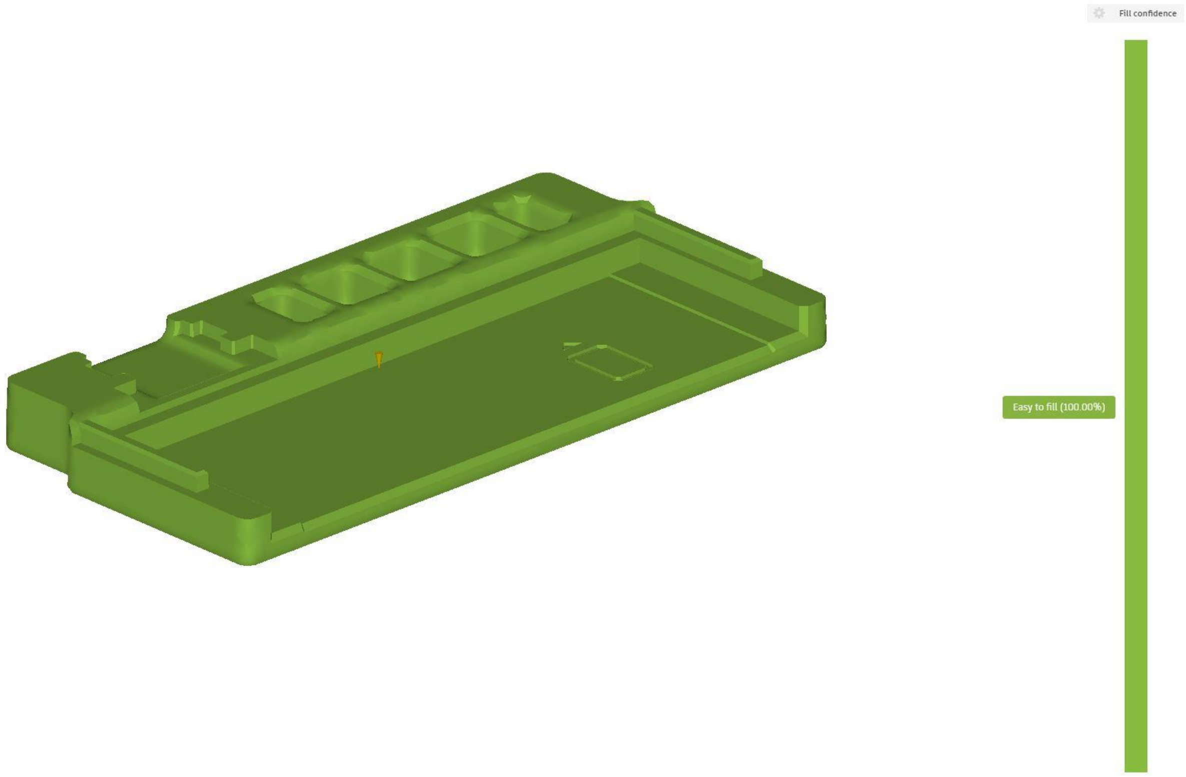

Fill confidence
Will not fill (0.286%)
Unlikely to fill (0.32%)
Difficult to fill (0.554%)
Easy to fill (98.84%)

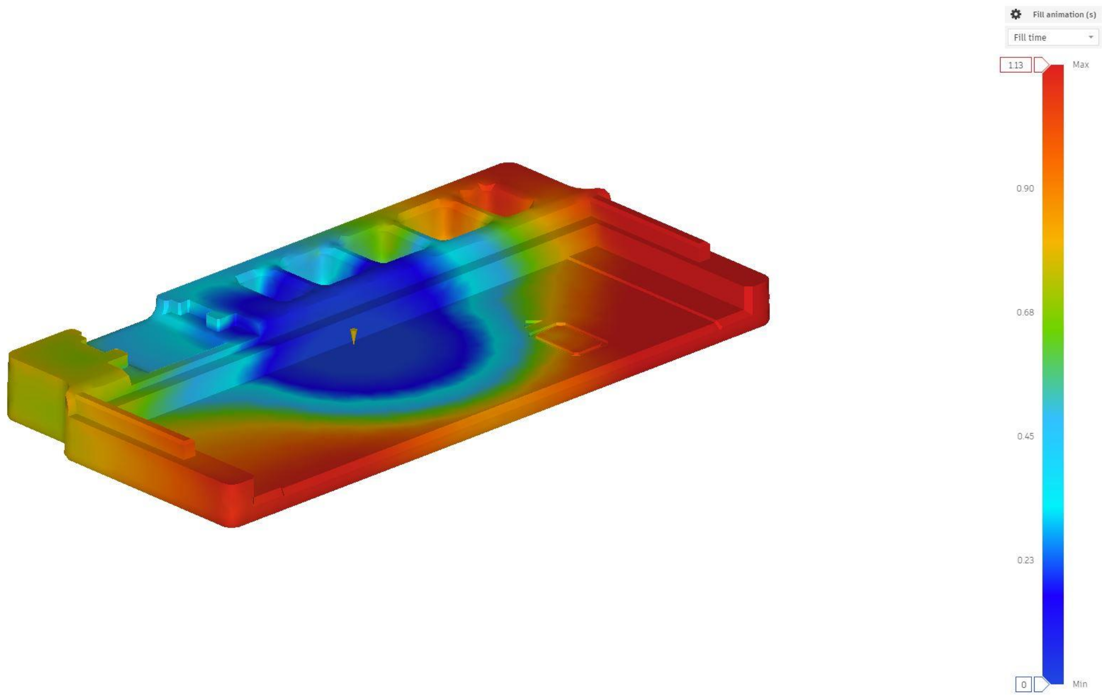

Flow-front temperature (°C)
230.988
Max
219.637
208.286
196.935
185.584
174.234
Min

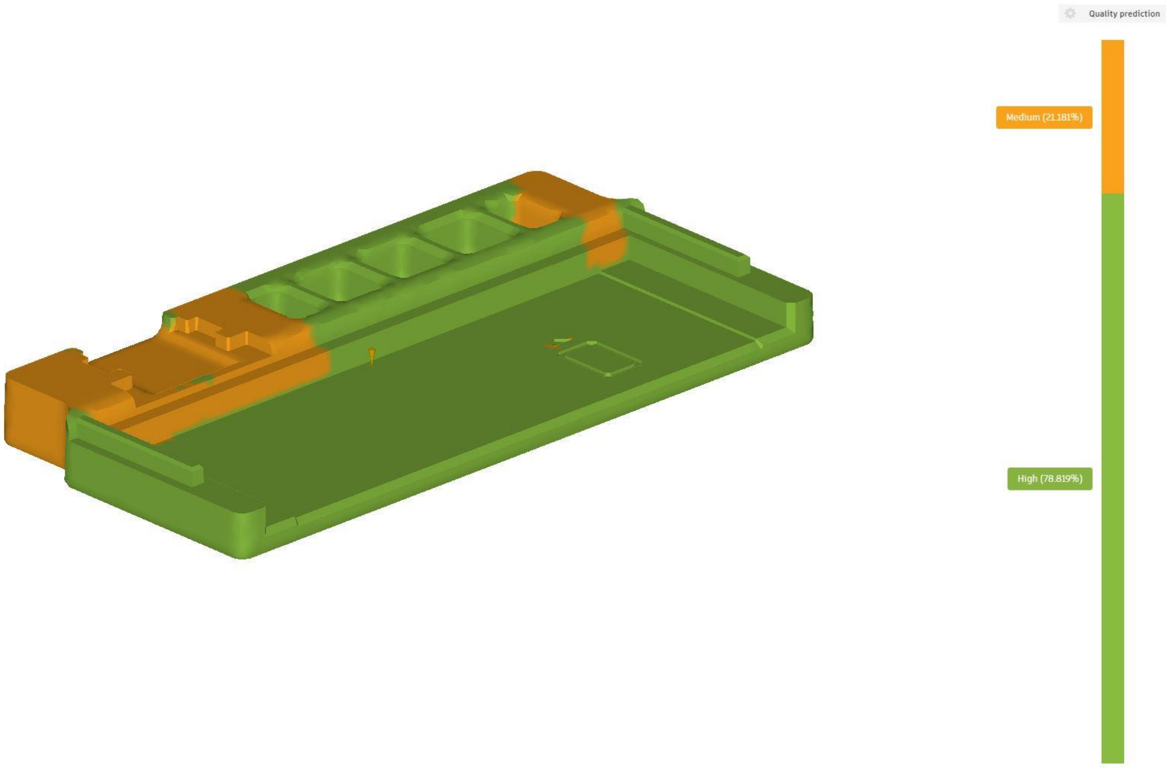

Injection pressure (MPa)
15.9
Max
12.7
9.6
6.4
3.2
0
Min

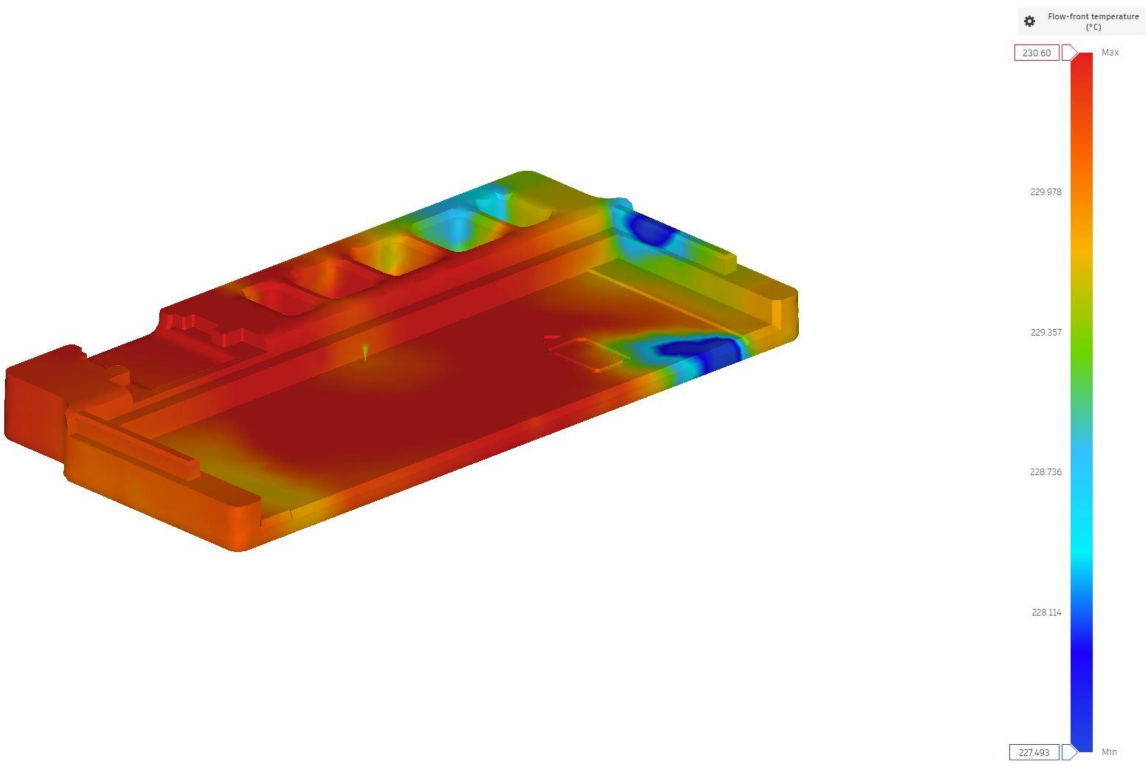

Fill animation (s)
Fill time
1.23
Max
0.99
0.74
0.49
0.25
0
Min

Part 3:

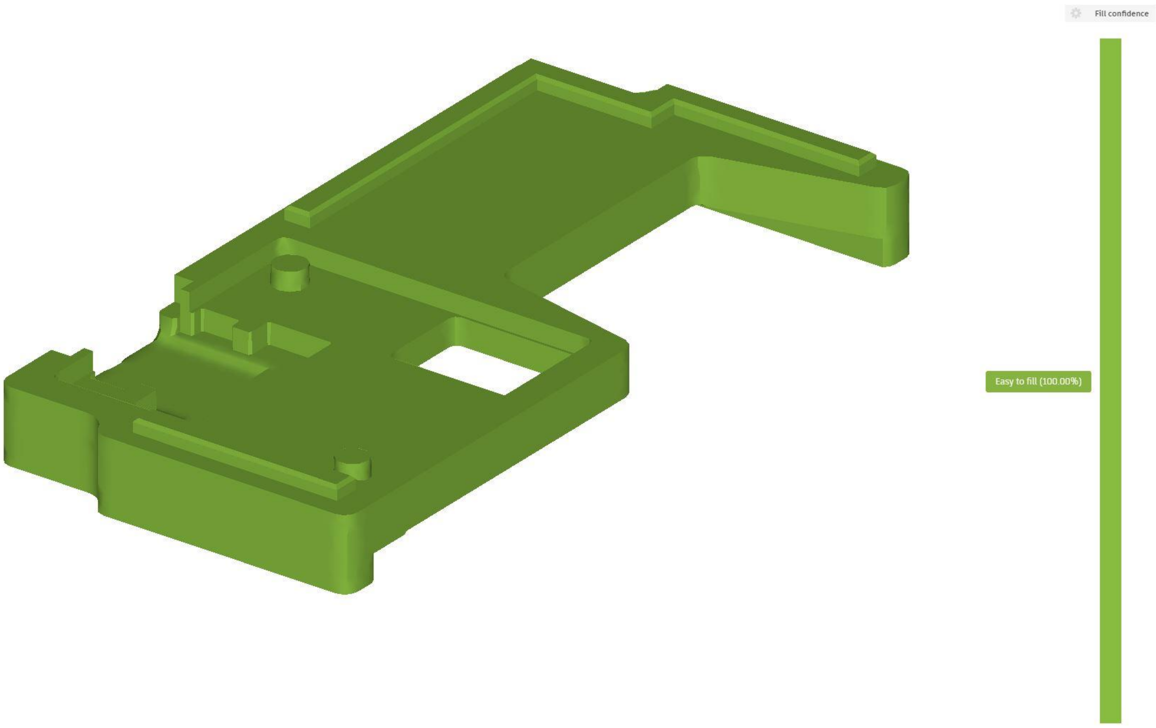

Fill confidence
Easy to fill (100.00%)


Fill animation (s)
Fill time
1.13
Max
0.90
0.68
0.45
0.23
0
Min

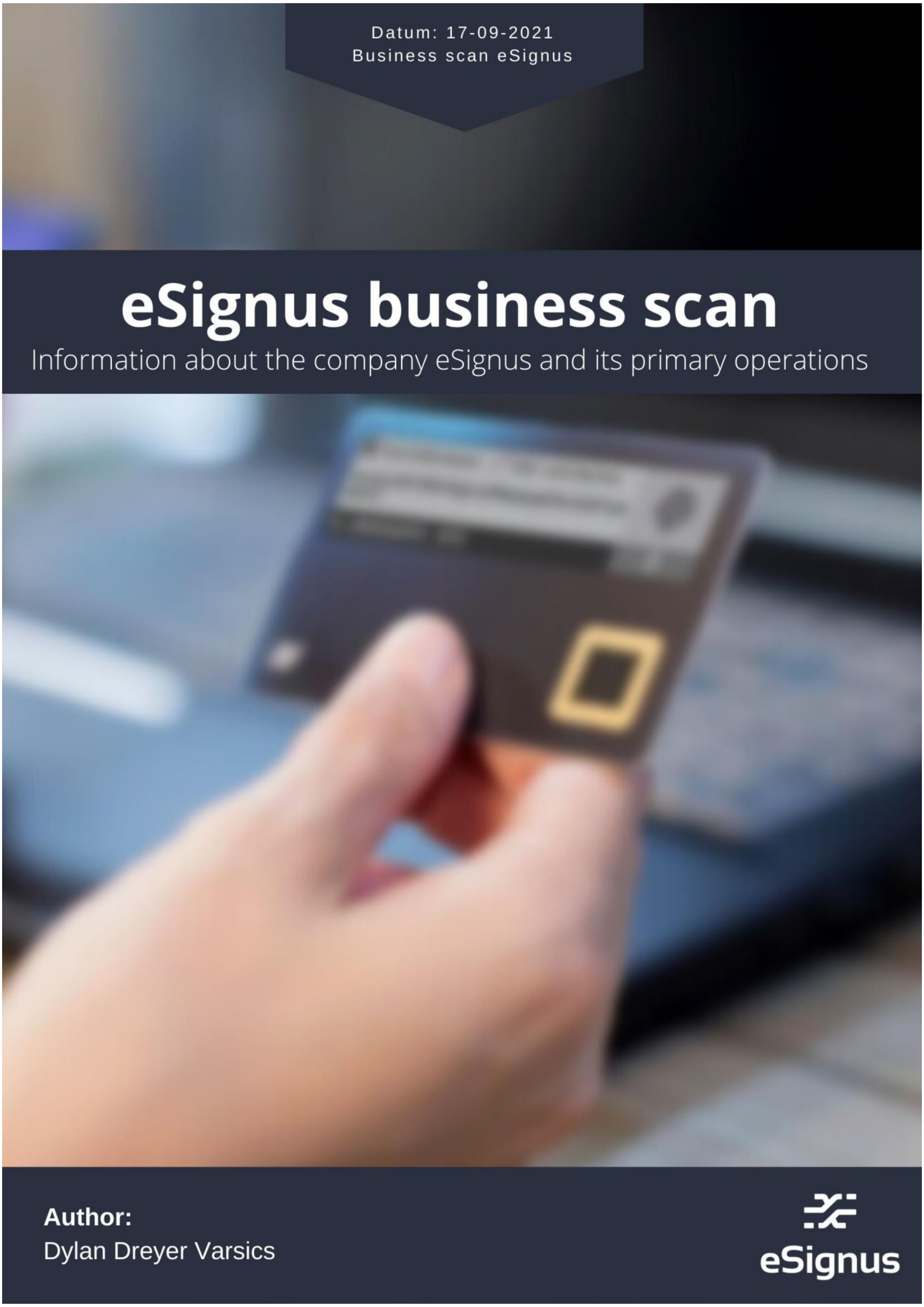

Quality prediction
Medium (21.181%)
High (78.819%)


Flow-front temperature (°C)
230.60
Max
229.978
229.357
228.736
228.114
227.493
Min

Extra simulation image (other design):



Attachment 2: eSignus business scan



Datum: 17-09-2021
Business scan eSignus

eSignus business scan

Information about the company eSignus and its primary operations

Author:
Dylan Dreyer Varsics

eSignus general business scan

Information about the company eSignus and its primary operations

17-09-2021 | Las Palmas, de Gran Canaria | Version 1.0

Client:
eSignus Security Solutions S.L.
Edificio II del Parque Científico y Tecnológico,
35017 Las Palmas de Gran Canaria=
Contact: business@esignus.com

Author:
Dylan Dreyer Varsics

Table of Contents

1. General business information

1.1 Business details

Business name: eSignus Security Solutions S.L.
Business adres: Edificio II del Parque Científico y Tecnológico, 35017 Las Palmas de Gran Canaria
Contact details: business@esignus.com

Figuur 1.1The HASHWallet

1.2 The product and business activities

eSignus is an international start-up company located in Spain, that facilitates the integration of the decentralized economy into business environments, delivering recognized and secure user experiences. The company is designing a hardware wallet where you can store crypto assets on (See figure 1.1) (Esignus, 2020). The advantages of using a hardware wallet is that they are more secure than soft wallets (Crypto news, 2021). eSignus designs and externally produces the hardware wallets. The software that supports the product is completely built inhouse (eSignus, 2021). The company brings together a team that is highly experienced in the financial, technology and cybersecurity sector and the team mainly exist of software and hardware engineers. The main office is located in Las Palmas de Gran Canaria.

eSignus has officially started in the first quarter of 2019 by starting to design a prototype and validating the product before launching the product on Indiegogo (eSignus, 2020). At the moment there are already multiple test units produced and the beta product is operational (figure 1.2). Also, the HOLa software is still in beta but it works well with the prototype hardware wallets. The team is working on improving the UI of the application and improving the software for the card.

Figure 7.2: Roadmap eSignus

After the first batches are delivered to the customers there will be made some improvements to the original product. Besides this there are future plans to produce more affordable cards with less additional features to cut production costs and offer more variety to the product portfolio. Now only the selected hardware wallet in the figure is in development (figure 1.3).

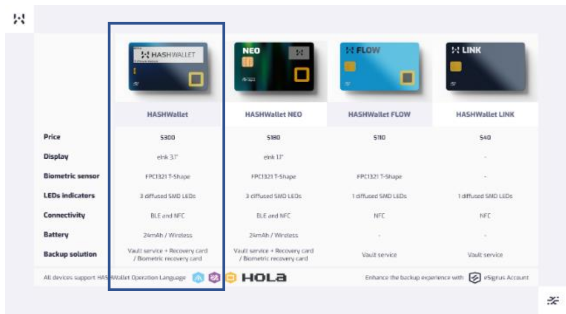


Figure 1.3 eSignus (future) product line-up

The core business model of eSignus is adding value by designing a totally secure hardware wallet for customers that would like to store crypto assets on them. eSignus has had a successful Indiegogo campaign where the company raised €64.240. Besides this the company receives financial funds from the European regional development program, to boost and promote technology research on the Canary Islands. Also, the company has won an award from the cybersecurity demo day and won the top innovative start-ups ideas at ICE (eSignus, 2020). With these funds the company can proceed the research and development of the product.

1.3 Product operation

The main goal of the product is to store crypto assets safely on a hardware / cold wallet. This has proven to be the most secure way to store crypto assets at the moment (Crypto news, 2021). The developers have worked hard to make the operation as intuitive as possible, because the product is quite technology advanced. If you tap the card it will turn on, for the first time use it should be connected to the application and the recovery card. After completing the setup, the card is ready to receive and make crypto transactions. For more information, please visit the main website.

2. Business environment

2.1 Suppliers:

The parts from the hardware wallet that eSignus produces are sourced from multiple international suppliers. This part is mostly regulated trough Card Lab (Card_Lab, n.d.) an external partner that focuses on R&D, design for manufacturing, the sourcing and production part of the hardware wallets. Their suppliers are in located in different countries around the world, and this makes the supply chain more difficult to manage. The product is also technology advanced and therefore specialised tools and many different hardware components are needed to produce the final product. Parts like the packaging and custom charger are designed within the eSignus group.

2.2 Customers:

The customer target group are defined in four groups. The first one is highly experienced in the sector of (cyber)security, finance or/and privacy and they have a hardware wallet for their crypto assets, they use it regularly. The second group have a certain awareness for security but not fully understand how to evaluate it. They have a hardware wallet, and they use it regularly. The third group know there is a security problem with soft wallets, but they are unable to evaluate a device. They own or are planning to buy a hardware wallet, but they practically do not use it because of its complexity and the risk of losing their assets. The fourth group of potential customers are the same as group three, but they don't care where there crypto assets are stored on. The assets are then stored on an exchange.

2.3 Competition

In the sector where eSignus operates are multiple different competitors with similar products. Most of these products have less functionalities, are less secure and do not come with a mobile or web application. With the additional features, many supported crypto currencies, premium look and feel that the HASHWallet offers, it is standing out of many competitors. But the first mover advantage has already been set by Ledger and Trezor. If the demand of the crypto asset stays rising, there should be enough room for growth. The most important competitors are listed (table 1).

Table 2 Main competion eSignus

Competition	
1. Ledger	2. BitBox
3. Trezor	4. D'Cent
5. keepkey	6. Keevo
7. Ellipal	8. Opolo
9. SafePal	10. Coldcard
11. SecuX	12. Satohip
13. CoolWallet	14. Archos
15. Keystone	16. Fuze

2.4 Business environment

eSignus operates in a fast-changing environment, therefor the management needs to make rapid decisions and changes to the fluctuating demand. The crypto market was in 2021 rapidly growing and is expected to grow even more in the future. In January 2021 there were 106 million global crypto users and before the end of June, 2021 the total amount of global crypto users has more than doubled to 221 million users (Figure 2.3). The huge growth rate has to do with the risk of rising inflations, the depleting U.S. dollar, and a decentralized finance (DeFI). Also, large corporations and investors like PayPal / Elon Musk adding crypto assets to their balance sheets have helped to increase the rate of crypto assets adoption (Portfolio Insider, 2021). With these growing expectations eSignus has a fair chance to launch their product successfully in the market. But the product will be influenced by the demand of crypto assets. If the demand is declining, then will the demand of crypto hardware wallets decline as well. Besides this there are more factors that could influence the hardware wallet demand. Like new methods to store crypto assets or soft wallets that become more secure.

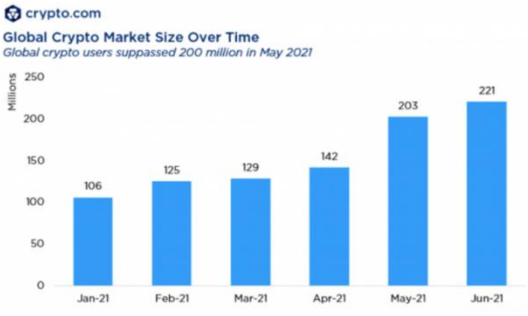


Figure 8.1 Crypto growh chart 2021

3. Business strategy

3.1 Business Mission

The mission of eSignus is to promote the mass adoption of a decentralized economy by offering secure and reliable products/services like the HASHWallet (eSignus, 2019).

3.2 Vision Statement

The vision statement of eSignus is to evolve to a decentralized world by facilitating the integration of the decentralized economy into business environments, delivering recognized and truly secure use experiences for mass adoption (eSignus, 2019).

3.3 Business objective

Delivering a hardware wallet where you can store crypto assets safely on to an international market before the first quarter of 2022.

4. Business processes

The primary processes at eSignus mainly consist of the software and hardware development (figure 4.1) for the HASHWallet and HOLa application. In the process flowchart (figure 4.2), the primary processes are coloured blue. The orange blocks are supportive processes that are important to finalize the product, the parts like the eINK display, processor unit, Flip Switch, NFC Chip, charger, and the battery are sourced from multiple international suppliers by Card lab. When all the parts are produced and sourced the wallets get laminated and checked for any quality problems (figure 4.3). After that it is ready to be tested and shipped back to eSignus. After eSignus receives the final product it is ready to be shipped to the customer. After sales is also done within the company. The after sales department resolves all issues that customers may have with their product.

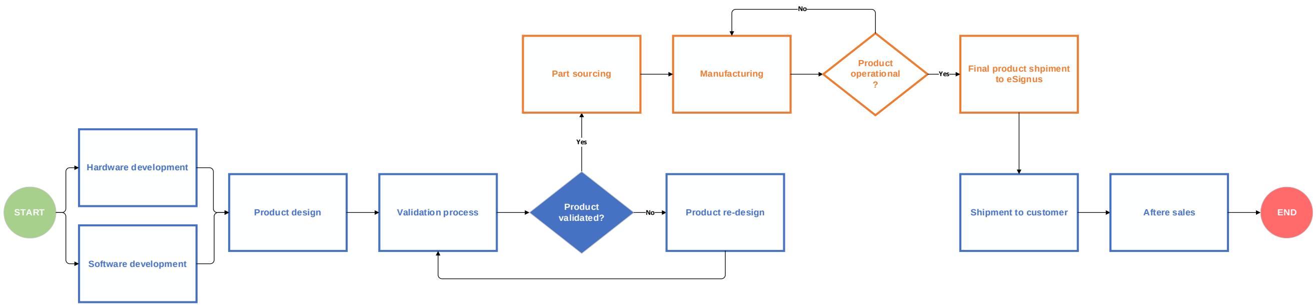


Figure 4.2 Primary flow chart eSignus

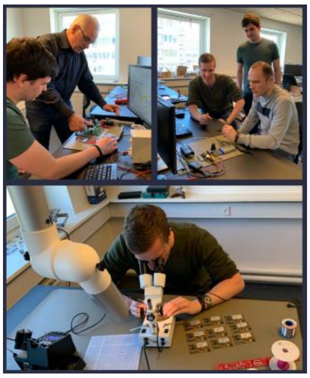


Figure 4.1 Development of the hardware wallet

Figure 4.3 Production of the hardware wallet.

Figure 4.4 HASHWallet prototype

5. Business structure & organization chart

eSignus has a horizontal structure without much hierarchy. The top-management exists of one CEO/CO-founder (Daniel Hernández Rogríguez), a second co-founder and CTO (José Ramón Sendra). eSignus also has a chief business development officer (Alexis Domínguez). For the middle management is Sebastian Unda the Lead UX & Designer and Claudio Molina is responsible for telecommunications. Besides these functions there are software, frontend/backend engineers and a graphic designer. For the supportive staff eSignus has a security and a marketing advisor. The team is cooperating much together to meet all the all-planned goals. As mentioned before there is not much hierarchy and everyone takes his/her own responsibility. The main decisions are made by the founders and the CEO of the company.

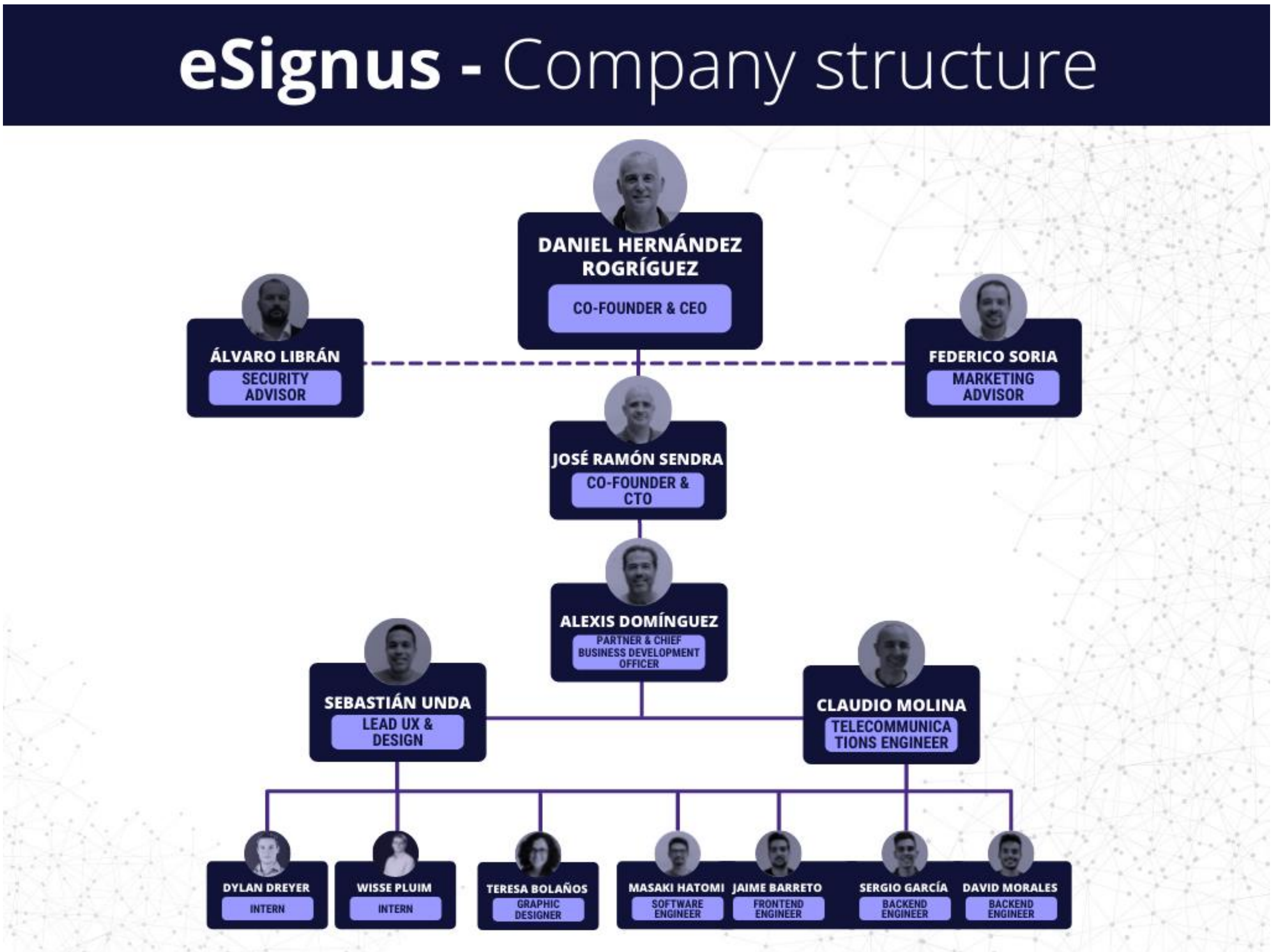


Figure 5.1 organization chart

6. Sustainability

6.1 Sustainability at eSignus

eSignus mainly focuses on the people and profit side of the sustainability circle (figure 6.1). For the company it is important that not only the employees feel well but also the customers. eSignus has a large fallowing base with a telegram group containing 1500 users. If a costumer / stakeholder has a question or comment about anything, the communication department will respond directly to resolve any issue or to respond to a comment. Besides this they listen very carefully to everything that the employees and stakeholders have to say. By this the company creates a sustainable culture within the company. eSignus has also goals to improve the office and to make the working experience better by providing everyone with the tools they require.

figure 6.1 People, planet and profits

6.2 Sustainability aspects for the internship assignment

The internship assignment will be set around the design and production of the dedicated charger for the HASHWallet (figure 6.1). Before the production of the charger many of the sustainability points will be addressed and taken in consideration while designing the charger. Not only does the charger need to be small enough to fit in the final packaging that already is pre-designed. But choosing the right materials to improve durability and making sure that it will not use too much power are important things that will be researched.

Figure 6.1 Prototype charger for the HASHWallet

Attachment 3: Plan of approach (PVA):

Plan of approach for the main internship assignment

Designing a secondary charger for the HASHWallet

Name: Dylan Dreyer Varsics
Student number: 2157127

Company Supervisor: Sebastián Unda

Supervisor Avans: Karin van der Steen

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1.1 Problem orientation

1.1 Background / Context

The project will be performed for eSignus an international start-up company that started in 2019. eSignus is located in Las Palmas de Gran Canaria, Spain and the company facilitates the integration of the decentralized economy into business environments by delivering recognized and secure user experiences. The company focuses on designing a hardware wallet where crypto assets can be stored on. The product is called the HASHWallet and after releasing this product, eSignus wants to develop more similar hardware wallets to expend the product portfolio (Hashwallet, 2021).

Mission statement:
The mission of eSignus is to promote the mass adoption of a decentralized economy by offering secure and reliable products/services like the HASHWallet (eSignus, 2021)

Vision statement:
The vision statement of eSignus is to evolve to a decentralized world by facilitating the integration of the decentralized economy into business environments, delivering recognized and truly secure use experiences for mass adoption (eSignus, 2021).

Business environment
eSignus operates in a dynamic and fast changing environment that has a quite high complexity to it. Therefor the management of eSignus needs to make decisions and changes rapidly to adjust to the market demand. The culture within the company is pleasant and there is not much hierarchy within the company. Everyone is treated the same way and every suggestion is taken seriously. This is often the case at smaller companies and start-ups.

1.2 Origin of the project

There is not yet an external charger for the hardware wallet. Therefor it is important that a charger is designed, produced, and validated for the first batch can be shipped with a charger that satisfies all the shareholders.

1.3 Problem exploration

For now, there is no external way to charge the HASHWallet that does not include wireless charging and stakeholders would like to have a second option of charging the hardware wallet. This is mainly because many customers do not have a wireless charger at home, require a faster charging method and/or would like to have a more redounded charging method as failsafe option when the battery has minor problems or when the battery is depleted after many charging cycles.

A battery capacity lifecycle will deplete after many charging cycles. As a hardware wallet could store many valuable crypto assets, it is highly important that there is a way to use the card even when the battery is depleted. Therefor only having a wireless charging method could be problematic to some customers what in the short term could mean less sales of the product. Having a second charging method will ensure that the eSignus holds it competitor position better.

> “While wireless charging is convenient, we believe that the user may not have access to one or may need much faster charging than an inductive charger can provide. Obviously, this feature will be shipped along with the other components absolutely free of charge for our supporters. (Masaki Hatomi, 2021)”

1.3.2 Problem statement

The main problem is to find a way to charging the HASHWallet from an external source that does not use wireless charging, because this method is already included in the product. The non-wireless charging method should be fast, secure, portable and the device should be usable while charging. This problem should be solved before the first and second production run. The first production run will facilitate 300 chargers for the founder edition HASHWallet (first version) and the second version of the charger will be designed for mass production (3000-5000 units in 2022). Therefor production cost and durability are important for the development of the charger.

1.4 project exploration

1.4.1 Stakeholder analysis

For the stakeholder analysis there has been made a stakeholder matrix to map all the stakeholders that are involved with this project (table 1.1). The key stakeholders are the project leaders, the engineering department, 3D designers, the investors, the assessor, Indiegogo backers and the suppliers that will produce the charger. These stakeholders will be updated daily with new information and updates about the project (managed cosily). The stakeholders in the secondary department (Yellow) will be informed and monitored. These stakeholders consist of competitors, assessors from Avans, and Gobierno de Canarias (local government that supplied eSignus with funds). The stakeholders in the third department (Green) are updated when new information is published. These stakeholders have a low influence and a lower interest then the main stakeholders.

Table 3.1 Stakeholde matrix

influence stakeholder	Low	Medium	High
High			• Sebastián Unda (project lead) • José Ramón Sendra (project lead) • Daniel Herandez • Aurelio (Engineering) • Alexis (3D designer)
Medium		• Gobierno de Canarias • Sodecan • Fondo Canarias Financia	• Indiegogo backers • External suppliers for parts (Digikey)
Low	• Dutch universities • European union • Labour unios • Simplex • Changelly • Indiegogo • Card_Lab • Plastic Logic	• Development department eSignus • Marketing department eSignus • Communication department eSignus • Spanish universities • Press and media • Canarias Avanza	• competitor • Assessor Avans

Interest stakeholder

1.4.2 The assignment

The client expects before the 12th of January to receive a fully functional first-, and second-generation charger for the hardware wallet including the full DMADOV documentation. The first and second version of the charger must be portable, offer a female USB-C plug and the second version must be faster, easier, and cheaper to manufacture. Durability and reusability will play an important factor for the second mass production variant of the charger.

The most important part of the research is to see which of the two final chargers is better from a durability and cost perspective view and to check what the final production costs will be. The final version should also be able to be produced on a larger scale. With the conducted research there should be a charger designed that fulfils all the requirements. The final goal is to deliver two finished chargers with all the features that customers require. These goals should be reached to stay in front of the competition and verify what exactly the needs are.

The problem could be solved by fallowing the DMADOV methodology and designing a charger that is not over complicated and does exactly what it supposes to do. Therefor it should be simple/cheap to manufacture, and the charger must meet all the requirements.

1.4.3 Defining the scope of the project

The scope of the project is the complete the defining, measuring, analysing, designing, optimising, and verification process of the two versions of the charger. The chargers will be realized by using multiple 2D/3D tools. DMADOV will be the leading project methodology. The whole documentation must be handed in before 12th of January. Everything else that falls outside these project boundaries will not be included within this project (table 2.2)

Table 4.2 In and out of the project scope

In scope	Out of scope
Full DMADOV research documentation	Designing different charging methods
3D and 2D Designs of the first and optimised version of the charger	designing a charger for a different hardware wallet
Prototypes of the chargers	Making more than the two final versions of the HASHWallet
Final version of the charger (founder edition HASHWallet charger – 300 units)	
Final charger for future HASHWallet production (mass production)	
Manufacturing research	
Customer research	

Final Deliverables:

- Plan of action (PVA)
- Full DMADOV project approach documentation (see figure 3.1)
- Charger designs in CAD Software (3D)
- Operational protypes (3D Printed versions of both chargers)
- Final Charger for the first batch (Founder edition HASHWallet - 300 units)
- Final Charger for future versions of the HASHWallet (Second batch 3000-5000 units in 2022)

Project objective

The project objective is to design a charger that can charge the founder and future editions of the HASHWallet´s. The charger must be portable, have a USB-C connector and be designed with durability in mind. The project must be finished before the 12th of January.

1.5 Main question

What is the most effective method to develop the first version of the charger for a production of maximum of 300 units and what is the most effective method to mass produce the final version of the HASHWallet charger?

2. Research foundation
2.1 Defining the research
2.1.1 Theoretical framework
Before starting this project, it is important to have a basic understanding of different charging methods, different battery types/specifications and to know what type of project tools to use to realize this project.

With the rapid growth of portable devices, the needs for finding efficient solutions to charge these products has increased. Therefor it is important to have a good understanding what type of method for charging lithium-ion batteries is the best to use for development of the charger.

> The demand for portable products is showing exponential growth with no end in immediate sight. Along with the overall growth in volume has come increased demand for greater features and functions. This combination has brought the issue of power management to the forefront of engineering design considerations. The overall success of a portable product will not only be dictated by its features and functions, it will also be influenced by how long it can perform before running out of power, the time it takes to return the batteries to full capacity and the life expectancy of the battery. Sound engineering design begins with a good working knowledge of batteries and battery charging techniques (Cope & Podrazhansky, 1999)

Project management methodology and tools:
For this project the DMADOV methodology will be used to guarantee that the project is orientated, analysed, designed, and is realised. To meet the required goals there will be used certain tools like 3D computer-aided-design software like fusion 360 and other 3D/2D software to visualize the final designs. The documentation part will be created with Microsoft Word, excel and Visio.

Important theoretical knowledge:
Different rechargeable battery types:
5. Nickel cadmium batteries
6. Nickel metal hydride batteries
7. Lithium-Ion batteries
8. Sealed lead acid batteries

Rechargeable battery used in the HASHWallet:
eSignus uses thin Lithium-Ion batteries in their HASHWallet, because lithium-ion batteries can be very light, thin and can be recharged for many cycles (when used correctly).

> Lithium-ion batteries (LIBs) are considered the pioneering technology that has been successfully adopted as a power source for wide range of applications including portable electronics and electric/hybrid electric vehicles (EVs/HEVs) after their commercialization by Sony Corporation in 1991 (Perveen et al., 2020; Duan et al., 2020; Tian et al., 2020). Despite their commercial success in numerous applications, LIBs have not been deployed in large-scale electrical energy storage (EES) applications due to elevated cost and limited supply of lithium resources over the coming years. (H.Qiao, 2012)

Different charging methods for Lithium-Ion batteries:
Li-Ion battery chemistries utilize a constant, or controlled, current and constant voltage algorithm that can be broken-up into four stages: (1) trickle charge, (2) constant current charge, (3) constant voltage charge and (4) charge termination (Cleveland & Dearborn, z.d.)

5. Trickle Charge
6. Constant Current charge
7. Constant voltage charge
8. Change Termination

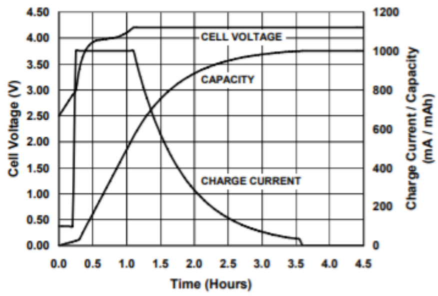

Figure 2.1 Li-Ion Charge profile (Cleveland & Dearborn, z.d.)

2.1.2 Define theoretical variables

In table 1.1 all the different variables of the main question “charging methods” are defined and separated in dependent, independent and moderator variables.

Table 1.1: dependent, independent and moderator varibles

Dependent variable	Independent variable	Moderator variable
Charger development	-	-
Battery/charger performance	Temperature and Humidity	Weather, Voltage, Amperages, Watts
Battery type	Materials	-
Battery capacity	Battery type	mAh - Resistance
User experience	User requirements	Home environment
Production materials		-

2.1.3 Conceptual model

In the conceptual model (figure 2.2) “charging methods” stands central from the main question. And the other depended, independent and moderator variables are used to map the relationships of these variables to the central main question “charging methods”.

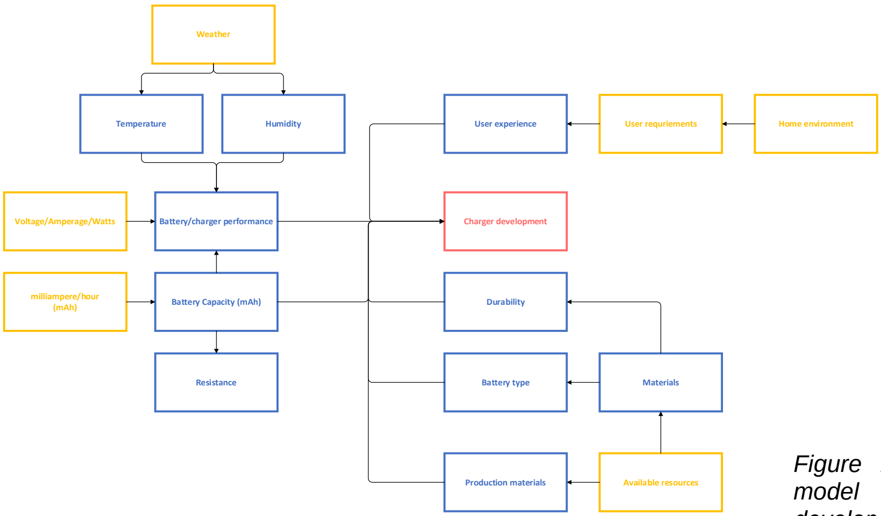

Figure 2.2 Conceptual model “charger development”

2.1.3 Sub-questions

Define:

- *What is the project approach and how will the goals be defined?*

Measure:

- What are the risks and how can they be measured?
- What is the schedule that must be met, and what are suitable milestones?

Analyse:

- *Which types of materials will be best suited for the mass production of the charger?*
- *How will the charger be durable, repairable, and recyclable?*

Design:

- *What charger design is best suited for a production size of 300 units?*

Optimise:

- *What type of adjustments must be made before the charger can be mass-produced?*

Verify:

- *What type of production method(s) will be best suited to produce both versions of the charger?*

2.2 Orientation to the required data

To answer the leading and sub questions it is important that the information and data is reliable. Therefor the variables and values are placed within table 2.2.

Table 5.2 Variables & Values

Variables	Programmes	Values
Dimensions	Technical drawings	Sizes are noted in: Milimeter (mm)
3D Files	Fusion 360 / 3ds Max	.FBX, OBJ or STL.
Document files	Word, Excel, Visio & PowerPoint	.PDF
Scrum	Notion	-
Communication	Telegram, Google meet & Notion	-

Research Data:

Sub-Dimensions	Indicators
User friendliness of designing a charger	The charger is so easy to use that there cannot made any mistakes like plugging it in wrong.
User experience of using different chargers	The consumer has already the required knowledge and items to charge the device.
Optimalisation used for production	The charger has a simple design, so the production part will not be complicated.
Portability of the charger	The charger should be light and small, so end users can take it easily with them.
Durability of the charger	The charger should function for at least five years without any defects under normal use. The charger should still function after drops from 1,5-meter heights.
Repairability of the mass production version of the charger	The mass production version of the charge should be repairable when a defect occurs. Costumers should also be able to repair their charger after warranty.
Recyclability/reusability of the charger	The charger should be quite easy to disassemble for recyclability and the charger should be reusable.

3. Project management

3.1.1 Program of requirements

what should the result be?
The result should be defining, measuring, analysing, designing, optimising, and verifying the creation of a charger that does not include wireless charging.

What is the pinnacle of ease of use?
This point is achieved when the end user and stakeholders are completely satisfied with the product. This means that the fallowing points are achieved:

- The charger will not damage the hardware wallet
- The charger is safe to use
- The charger is portable
- The charger is easy to use
- The charger is easy to disassemble
- The charger is recyclable
- The battery health is not influenced by the charging method
- The battery is charged faster than using the wireless charging method

What is not doable now?
- Designing an over complicated charger
- Using materials that are not widely available

Functional and operational requirements:
Table 3.1 Requirements charger

Functional requirements of the charger	Design Parameters
The charger will not damage the hardware wallet	Minimal friction
The max weight of the charger is	<100g
Minimal operational temperature	0-40 °C
Minimal and maximal charging speed	0-100W
The charger must have a USB connector	Type C
The dimensions of the charger must fit in the current packaging dimensions	138 x 81.5 x 35 mm (L*W*H)

Operational requirements of the charger
The charger must be easy to use
The charger must work with the new HASHWallet design
The charger will not damage the hardware wallet
The charger is portable and easy to carry
The charger must be easy to disassemble for repair or recycling
The battery health is not influenced by the charging method (under normal conditions)
The dimensions of the charger must fit in the current packaging dimensions
The charger does offer minimal to no wear on the HASHWallet
The charger must charge faster than using the wireless charging method

3.2 Project approach and organization

3.2.1 Project approach

The project will be approached with the DMADOV methodology to ensure that the project is well defined, measured, analysed, designed, optimised, and verified. DMADOV has been chosen for the leading project management methodology, because there is room for optimising the design and verifying the result. The Double diamond, Agile methodology focusses more on the development of software like the waterfall mythology does as well. That is why DMADOV will suit the project needs better. For managing the project teams, an agile framework will be the leading approach. With the help of a Kanban board every team member knows what their responsibility is. The online software tool is called Notion and within this application all team members communicate between different sprints. All the milestones are shared and processed within Notion.

3.2.1 Project organisation

The lead of the project consists out of Sebastian Unda and José Ramón Sendra. The other team members are consulted when a decision must be made. Within the project there are at every phase of the DMADOV cycle, Go and No-Go moments where the lead will determine if it is feasible to continue with the project. On the commination part there is every morning a short meeting planned where every team member tells what they have achieved last day and what they are planning to do. This is done with the help of the Kanban board within Notion. Besides this there is at the end of the week a general meeting to reflect on the learning processes.

The client will be satisfied when the project will be finished with all the required goals before the deadline of 12th of January 2022.

3.3 Planning

3.3.1 Project phasing

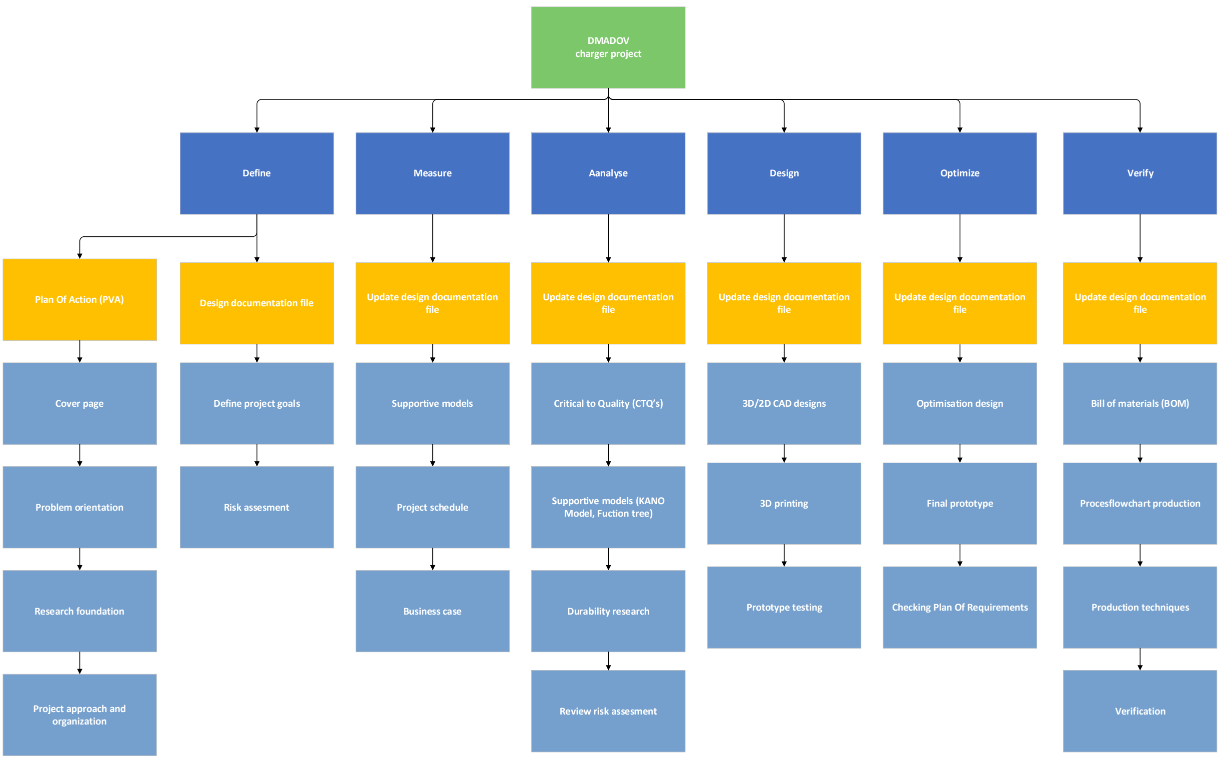

Figure 3.1 WBS of the charger project

3.3.2 Activities

All the activities are noted within table 3.1. In Table 3.2 a RACI Matrix displays who of the team member is responsible, accountable, consulted, and informed at every phase of the project.

Table 3.1 Phases of the project defined

Phase 1: Define - Plan of action (PVA) - Cover page - Problem orientation - Research foundation - Project approach and organisation - Define project goals - Risk assessment	**Phase 2: Measure** - Supportive models - Project schedule - Business case	**Phase 3: Analyse** - Set-up up CTQ´s - Kano model - Function tree - Durability research - Final specifications
Phase 4: Design - First 2D Designs - First 3D CAD designs in 3ds Max & Fusion 360 - Feedback on designs - 3D printing first design - Prototype testing	**Phase 5: Optimise** - Optimise and changing design flaws - Final prototype - Checking plan of requirements	**Phase 6: Verify** - Creating Bill of materials (BOM) - Process flowchart for manufacturing processes - Required production techniques - Final verification of project

Table 3.2 RACI Matrix

Project	Dylan	Sebastián	José	Daniel	External partners
1. Documentation – research paper	*R*	*A*	*C*	*C*	*I*
2. Define	*R*	*A*	*C*	*C*	*I*
3. Measure	*R*	*A*	*C*	*C*	*I*
4. Analyse	*R*	*A*	*C*	*C*	*I*
5. Design	*R*	*A*	*A*	*C*	*I*
Designing the chargers (3D)	*R*	*A*	*C*	*C*	*C*
Prototyping & Testing	*R*	*A*	*C*	*C*	*I*
5. Optimise	*R*	*A*	*A*	*C*	*I*
Final Design Mass production	*R*	*A*	*C*	*C*	*C*
6. Verify	*R*	*A*	*A*	*C*	*I*
internal communication	*R*	*R*	*R*	*R*	*I*
External communication	*A*	*R*	*R*	*R*	*I*
Manufacturing	*C*	*C*	*R*	*C*	*C*

Table	
Responsible	*R*
Accountable	*A*
Consulted	*C*
Informed	*I*

3.4 Risk analysis

3.4.1 Internal Risks

In the two tables below the main internal (table 3.3) and external risks (table 3.4) have been analysed/described in events, change, effect, precautionary measures and curative measures.

Table 3.3 internal risk analysis

Event	Change	Effect	Precautionary measure	curative measure
Miscommunication trough language barrier	Above Average	Errors during the project phases	Ask on time for feedback and make sure everyone is allied.	Make new agreements within the project group about communications.
Not enough clear communication within the project group	Average	Reduced performance	Using scrum methods like Notion and planning a daily meeting	Inform the project lead about the problem.
Deadlines are not met because of problem complexity	Average	Delay in final product	Creating an optimized and realistic planning	Create a meeting and make sure that everyone meets the required deadlines.
The designs are not correct	Average	The project will take longer to complete	Making sure that all the information about all the parts are public and up to date.	Sparring with the team to make sure that everyone is up to date.
Group member stops or suddenly becomes ill for a long time	Low	The rest of the group will have more work and tasks to finish and maybe miss deadlines	Stick to the planning and adjust the planning as this problem occurs.	Hiring a new group member or changing deadlines if possible.
Project does not meet requirements	Low	Disappointing results that could impact the project feasibility	Doing research about the feasibility of the project and setting up a stage gate mode.	If project is not feasible directly stop at a stage gate (No-Go)
development costs are too high.	Low	Project is not feasible anymore	Go/No Go gates at the phases of the project	Make new estimates or stop the project.

3.4.2 External Risks

Table 3.4 external risk analysis

Event	Change	Effect	Precautionary measure	curative measure
Parts can not be sourced on time	Below average	Project delay	Source parts as soon as possible when the specifications are complete.	Try finding an different supplier that can deliver the required parts
Issues with production partner	Below average	Project delay or in rare cases project cancelation	Keep in contact with the external production partners.	Inform the project lead and if the production part cannot be completed, searching for a different supplier.
Issues with external stakeholders	Low	Delay in final project, communication problems and/or reduced project performance	Keeping stakeholders up to date about the progress of project.	Bringing out a statement to the stakeholders.
Law and regulation changes	Low	Could impact the company	Keeping up to date with new regulations	Try finding a solution around the new regulations.

Cost-benefit analysis

For the creation of this project the main expense will be the research and development of the charger. The project team will be working on realizing this product, therefor the costs will increase. Besides that, there are material costs and transport costs. These indirect costs are dependent on how many units needs to be manufactured. In table 3.6 and 3.7 all the estimated costs for the first and second batch of the charger are calculated. The total development costs for this project will be (€16.015,50) including the production of the first 300 units and the second batch of 3000 units. The total price of a single charger will significantly decrease when the production increases.

The main benefits of completing this project are that the HASHWallet will have an extra charging option, therefor the product will suit better to many customer requirements. This will increase customer satisfaction and improve the competitor position. Besides this there will be a failsafe option when the battery is charged for many cycles. The HASHWallet will stay operational even with minor battery flaws or when the battery is not rechargeable anymore. This is for such a product an important feature, because in many cases there will be stored a lot of valuable crypto assets on.

Table 6.5 General costs and benefits

Cost
Research and development expenses
3D Printing expenses
Material expenses
Prototype shipping expenses

Benefits
Increased research and developing progress (R&D)
Having an extra charging option (failsafe)
Increased competition advantage
Increased customer satisfaction

Table 3.6 Cost estimates of the first version of the charger

Estimate costs first version (300 units):	Estimate costs: in €
Total internal wages for employees	€2500
Aurelio´s laboratorial expenses (R&D)	€2500
Material expenses	
- Contacts (300 units)	€ 186
- USB-C connectors (300 units)	€ 225
Manufacturing expenses	
- 3D printer with accessories (residual value: €200)	€350
- Lab pick and place system	€2000
- 300 printed circuit boards	€450
- **Plastic case production (300 units)**	
- Chassis production with SLS printer and painting (300*€3)	€ 900
- Final mounting boards to case (30 seconds*300/60=150 min) (€35 uur)	€87.50
- Gluing top to bottom part charger (60 seconds*300/60=300 min) (€35 uur(	€175
Transport costs	€500
Total project cost for the first version	**€ 9.873**
Total cost per unit before depreciation	**€ 32,91**

Estimate costs second version (3000 units):	Estimate costs: in €
Total internal wages for employees	€2500
Material expenses	
- Contacts (3000 units)	€ 186
- USB-C connectors (3000 units)	€ 225
Manufacturing expenses	
- Injection Mould total expenses (3x€1500)	€4500
- Lab pick and place system	€2000
- 300 printed circuit boards	€800
- **Plastic case production material (3000 units)**	€ 600
- Electricity, labor and, materials for case production	€ 3000
- Final mounting boards to case (30 seconds*300/60=1500 min)	€ 500-750
Total cost project for the second (mass production) version	**€ 14.436**
Cost per unit	**€ 4,81**