Development of a Base Station for a Control Center

Vigan Bytyqi and Martin Mellstam

DIVISION OF PRODUCT DEVELOPMENT | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2016

MASTER THESIS

Development of a Base Station for a Control Center

A product development project

Vigan Bytyqi and Martin Mellstam

LUND UNIVERSITY

Development of a Base Station for a Control Center

A product development project

Published by

Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Machine Design for Engineers (MMK820)
Division: Division of Product Development
Supervisor: Katarina-Elner Haglund
Examiner: Damien Motte

Abstract

In this thesis, the objective was to design a base station for a startup company as a compliment to their main product, a control center device. The thesis resulted in a prototype that worked as intended and it fulfilled all desired criteria; charging ability, mountable on walls and placeable on flat horizontal surfaces. The prototype is divided into two parts: One unit, the station, and one unit that is designed as a shell for the control center. The latter allows the control center to receive charging, be placed easily on the station and allow it to stand on a flat horizontal surface. The company is very pleased with the results and looks forward for further development.

Before generating any concepts, customer needs were identified through interviews from potential customers and lead users. The interviews got interpreted and evaluated which resulted in six complete product concepts. One of the concepts was chosen the best with highest score and also received the most positive feedback from the company.

A prototype was built to represent the winning concept as close to a real product as possible. It included enough working parts to be able to prove the concept and give a better understanding of the product. Tests were made during the development process to make sure that everything worked properly. The thesis was completed successfully and satisfied both the development team and the company.

Keywords:

Base station, product development, design, customized

Sammanfattning

I den här avhandlingen var uppdraget att designa en basstation för en produkt för ett startup företaget som ett komplement till deras huvudprodukt. Produkten är ett kontroll center för fjärrstyrning av andra enheter. Den här rapporten resulterade i en prototyp som fungerade som den var tänkt och fullföljde önskade kriterier; laddningsmöjlighet, monterbar på väggar och placerbar på plana horisontella ytor. Prototypen är indelad i två delar: En enhet, stationen, som monteras på väggen och ger trådlös laddning och en enhet som är designad som ett skal för kontroll centret. Det sistnämnda tillåter kontroll centret att ta emot trådlös laddning, att enkelt placeras på stationen samt tillåta att ställas på en plan horisontell yta. Företaget var väldigt nöjda med resultatet och ser fram emot vidare utveckling.

Innan konceptgenereringen påbörjades identifierades kundbehov genom intervjuer från potentiella kunder och nyckelpersoner. Intervjuerna översattes och utvärderades vilket resulterade i sex kompletta produktkoncept. Ett av koncepten blev utvalda till det bästa med mest poäng och mottog bäst respons av företaget.

En prototyp byggdes för att representera det vinnande konceptet så nära en riktig produkt som möjligt. Den innehöll tillräckligt med fungerande delar för att bevisa konceptet samt ge en bättre förståelse av produkten. Tester utfördes under utvecklingsprocessen för att försäkra om att allt fungerade korrekt. Den här avhandlingen var framgångsrikt genomförd och gjorde både utvecklingsteamet och företaget nöjda.

Nyckelord:

Basstation, produktutveckling, design, kundanpassat

Acknowledgments

This master thesis is the final part of our Mechanical Engineering studies. We got the opportunity to write it at the start-up company Animus Home in collaboration with the Division of Product Development at the Faculty of Engineering LTH.

We would like to especially thank Fidan Bytyqi and Vatan Bytyqi at Animus Home for their everyday inspiring attitude and encouraging support. Also, we would like to give a special thank to our supervisor Katarina Elner-Haglund and examiner Damien Motte at the Division of Product Development for their advices and feedback. As well, thanks to the staff members of the Faculty of Engineering LTH at Lund University and for the supply of equipment and tools that were really helpful for this thesis. Lastly, thanks to all people who participated in our interviews and answered our questions.

It has been a great educational journey full of new experiences. Now, we look forward to new opportunities and challenges.

Lund, June 2016

Martin Mellstam & Vigan Bytyqi

Table of contents

1 Introduction

This section introduces the company, the assignment and the purpose of this project.

1.1 Background

Animus Home is a start-up company that develops communication solutions within the area of Home Automation (HA). The solution, containing a physical product (Animus Heart) and corresponding software, allows smart devices in private homes to communicate to each other through a local network. This developed system will integrate different smart home devices from all kinds of producers and protocols into one universal platform. Possible devices can be anything from a smart TV or smart light bulb to network cameras and sensors. All of these devices are able to communicate to each other through the Animus Heart and the user can then create functions for the home. Anything from critical functions as, alarm systems and energy saving systems or just something cool to have functions, like a party-mode function. All of these functions and devices are then navigated through the Animus Home app.

The company has identified a need to ease the user experience for people to navigate their smart homes. Until today, the HA market has focused a lot on the technology and not on the end users, which creates a big gap between what exists and what is actually needed. By introducing a designated control panel (CP) as a complementary product for their home automation solution, Animus Home believes to fill this gap. The CP consists of a touchscreen tablet that runs the User Interface (UI) of the system and allows the user to control all the connected devices wherever they are in their home. It should be able stand on a flat horizontal surface or mounted on walls. Also, the CP should have the possibility to be charged in its docking station (DS). For this reason, Animus Home has decided to develop a DS for the CP, which will increase the user experience of the whole product.

1.2 Assignment

From an already proven market and a base product in the Animus Home portfolio, the company identified some issues that need to be solved for the upcoming product. This means that a docking solution for the CP needs to be developed. The project contains two main issues that need to be investigated and analyzed.

The first is to develop a construction that allows the CP to easily be mounted and dismounted on the DS. The CP will be removed from its position when the user needs it in other locations around the home. The DS will be stationed on either two places: as a wall mount or on a plane horizontal surface.

The second is to provide charging possibilities from the DS to the CP. Existing charging technologies will, therefore, be evaluated to find a suitable solution to implement. Power to the DS will be through a 5V power adapter from a 230V wall outlet.

The list below covers issues derived from the main ones mentioned above. They will be further examined during the development process.

- How the CP will be charged
- How the DS will be mounted on the wall
- How the CP will be attached on the DS
- How the DS will stand on flat horizontal surfaces
- The shape of the DS
- Does the DS bear the weight of the CP and other forces on it during mount and dismount
- Choice of material
- The station is supposed to be a part of the home environment. This sets rules of how the design should look and fit into the surrounding environment.
- The interaction between product and user depending on where it is stationed
- Allow power supply connection from a regular 230V wall outlet to the DS

1.3 Purpose

The goal for this project is to understand the usage of home automation systems in the homes and develop a DS for the company's CP. By investigating how the CP and similar products are used in the homes today the team will bring a solution to the issues. Known product development processes and design methods will be used during this project to reach best possible results.

A personal goal in the team is to come up with innovative ideas and solutions. Ideon Science Park, the environment of which the project will be worked in, is often called Silicon Valley of Sweden. This will strongly stimulate the team's creativity and will of hard work in the project and help reaching the goal.

The project will not only bring new knowledge to the development team but in the process they will contribute the whole HA market with valuable research material that will strengthen future product developments. Most beneficial in this will be the end customers who will get their needs satisfied. The end user will therefore play an important role in the development process.

2 Methodology

This thesis applies different methodologies and approaches throughout the project. As mentioned before, the focus is on product development processes, interaction design methods and material selection. To perform these actions, the team uses literature as guidelines and different kind of tools, which are explained in this chapter. The reasons for these choices are because of earlier experiences with these methods, their reputation and recommendations by professionals and teachers. The delimitations of the used methodologies are also explained.

2.1 Theories

For product development processes, the book by Ulrich and Eppinger (U&E) [1] is used. Their methods cover a big part of the thesis and it is a common book, used widely within the area. However, the process is adjusted after this project's preferences. The process explained in the book is generic and should be used as a tool or guideline to product development. Most of the steps are covered in the project but with delimitations that are mentioned later in this chapter. The main process that U&E promotes is displayed in the figure 2.1:

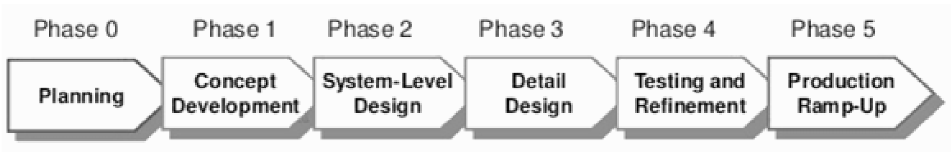

Figure 2.1 Product development process from Ulrich & Eppinger [1, p. 14]

In this thesis, only the planning and concept development phases are executed. The focus is especially on concept development where detail design and testing and refinement are implemented in some ways. All phases are not included due to lack of time in this thesis.

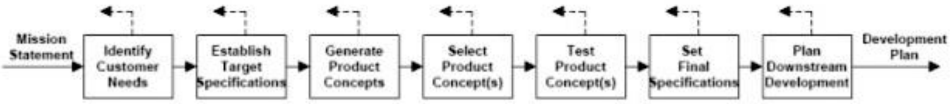

Figure 2.2 Concept development process from Ulrich & Eppinger [1, Exhibit 2-3]

The concept development, as seen in the figure 2.2, is the most detailed part of U&E's product development process [1, Exhibit 2-3]. Every phase is covered and a prototyping part is added between selecting and testing product concepts. U&E's processes have the possibility to be iterative - something that may happen if needed. It is difficult to predict the outcome of a development processes. Unexpected happenings can occur which can lead to revisits of certain phases. For example, customer feedback in the prototype stages can result in new minor design changes.

In addition to U&E's product development processes, one more literature book is used in this thesis - Bruder's book about plastics [2]. Bruder's book is used as a guide to choose the right materials for the product and what design properties to consider regarding manufacturing.

2.2 Tools

During this thesis, both physical and computer aided prototypes are made. To make the prototypes there are some tools in disposal for the team to use.

- **CAD** - SolidWorks is a software that is used to create complex computer models.
- **Illustrator** - Adobe illustrator is used for creating illustrations describing different methods and processes.
- **Maxwell Studio** - Maxwell Studio is a rendering software used for creating rendered images of the 3D models in different environments.
- **3D printing** - Complex 3D-printed physical parts with an SLS machine will be used for the prototyping. This tool gives the development team freedom to be innovative and not be limited in the constructions.
- **Handcrafting tools** - The team has access to workshops with conventional handcrafting tools for simple and quick prototyping.
- **Digital multimeter** - A digital multimeter was used for the testing of power and power efficiency.
- **Arduino Software** - Is used for programming microcontrollers.

2.3 Delimitations

Developing new products can be quite comprehensive and since time is limited for the project, delimitations needs to be made. There are some aspects of the project that the team will only go through briefly or not consider at all. This way the focus can be set on the parts that are most important for the product at this stage. Mainly, the focus will be on the concept development process, including everything from identifying customer needs to making concept prototypes and test them. Economic aspects and marketing strategies will not be something that is investigated thoroughly. Manufacturing possibilities will be considered, but mainly in aspects of material choice and design for manufacture.

The product that will be developed is based on a 7” (inch) Nexus First Generation tablet provided by the company.

Figure 2.3 Tablet used for this project. Front side to the left and back side to the right.

2.4 Benchmark

The concept development part started out with a benchmarking of existing products. The HA industry has become very trendy lately and doesn’t offer a lot of products that are relevant for this thesis. Therefore, a benchmarking of a few existing HA products have been evaluated and some similar products from other areas. These products cover different aspects of the intended product such as wall mounts, charging possibilities, placement, angles and orientation on tables or walls. These aspects come from mount accessories for products like TVs, mobile phones, tablets, smart watches, home alarms and music devices.

Some devices, similar in function or usage to the DS, were selected for further investigation. These products are already established products in the market by different companies and used in their specific environments. By investigating these products, valuable information were received about different solutions and what the needs are.

The benchmarking started off by browsing what exists in the stores today with the current market trends. Some specific stores in the close area were chosen for the investigation. These were MediaMarkt, Elgiganten, Clas Ohlson, Miljögården, HiFi-klubben, Teknikmagasinet, GameStop and Apple Store. They have a large variety of products that are similar or have similar functions as the intended product. The products are well established and comes from both Swedish producers as well from international companies. Beside the physical stores visited, web shops were also browsed. This covers products and companies outside the country that are similar to the product that is to be developed.

Firstly, the browsing lead to a large number of products that had something related to the intended product. It could be anything from a special charging technology to a nice design feature. All of these products are listed in the list below. Since some of these were more interesting to investigate than others, the team had to make a choice of which ones to bring to the Competitive Benchmarking Chart.

Mass selected list:

- Quell & Co
- Nest
- NuBryte
- Apple Sena leather case for Apple Watch
- Apple Elevation Lab nightstand for Apple Watch
- Apple iPhone lightning dock
- Apple Belkin portable tablet stage stand for iPad
- Apple Kensington secureback counter top stand for iPad
- Apple Twelve south hirise stand for iPhone and iPad mini
- Apple Twelve south compass stand for iPad
- Apple Watch magnetic charging dock
- Apple Belkin valet charge dock for apple watch and iPhone
- Exelium UP Wall Mount - two bases
- Doro Phoneeasy 110
- Gigaset SL450HX
- Vogels TMS 1030 tablet flex pack
- Smartphone holder with ball joint
- Sanus iPad mount

- Sonos wall mount
- Belkin charge and sync dock
- Belkin express dock
- Belkin powerhouse charging dock
- Vogel TMS 301 RingO Wall Pack for iPad
- KÖNIG Universal foldable stand for tablets
- IKEA induction charger

Finally, ten of the products from the list that proved to have most similarities with the intended product were chosen. These are listed in the table below with a short description of what they are used for and their special feature according to the development team.

Table 2.1 Selected competitive products.

		Description
Quell & Co Spool dock		This is a product for docking iPhones. It is a simple table dock with soft and scratch friendly materials.
Nest Thermostat		This is a smart thermostat that is mounted on the wall by replacing a wall switch. It has a clean and simple design with premium feeling.
NuBryte Touchpoint		This is a smart switch with a touchscreen which replaces your existing wall switches in your home and allows remote control.
Apple Elevation Lab Nightstand		This is a docking station for Apple Watch products and charges through induction charging. It hangs over the dock and is held in place by magnetic connection.
Apple Twelve South Compass Stand		This is a simple table stand for iPads or iPhones without any charging capability. It can be folded to take less space.
Gigaset C430		This is a wireless home phone with a base station that gives charging to the phone by contact spots underneath.

Smartphone holder with ball joint		This smartphone holder keeps both the phone and itself in position by suction cups. A ball joint holds the two suction cups and allows the phone to be aligned freely when mounted.
Vogel TMS RingO		This is a tablet holder that comes in two pieces. One small circle that gets mounted on the wall and one iPad-case that is customized to fit with the circle on the wall.
König Universal Stand		This is a tablet stand that grips the tablet and allows it to stand on a flat surface, angled or rotated in any position.
IKEA Induction Charger		This is a induction charging plate that charges phones wirelessly. This product is interesting to investigate because of its charging technology.

2.5 Mission statement

The mission statement communicates the purpose of the business and product goals, which is given by the company Animus Home. It is given to the development team for a better understanding of the market, business idea, assumptions and goals of the product.

Table 2.2 Mission statement.

Product description	• Docking station for a 7" Nexus First Generation tablet with charging possibility.
Benefit Proposition	• Simple mount and dismount from docking station when needed around in the house. • Charges battery when tablet is docked. • Mountable on walls or placed on flat horizontal surfaces. • Designed for home environment. • Intuitive interaction with user.
Key business goals	• Should fit the Animus Home product design language. • Become a natural complement of every Animus Home system. • First product introduction 4th Q 2016.
Primary market	• Customers of Animus Home: House owners.
Secondary market	• Customers of Animus Home: Apartment owners.
Assumptions and constraints	• Mountable on regular interior walls (concrete, wood, plaster etc.). • Stand on all interior horizontal flat surfaces (solid). • Designed for the 7" tablet developed by Animus Home. • Sold as a part of the Animus Home package, not as a single unit. • Power supply from 230V wall outlet.
Stakeholders	• Purchasers and users. • Manufacturing operators. • Service operators. • Distributors and resellers.

3 Identifying customer needs

Identifying customer needs is a crucial part of the concept development process. It is important to find a sufficient amount of customers so that every type of need gets presented. There are needs that can be more difficult to find such as latent or hidden needs. Therefore, finding customers that cover all types of needs is ideal.

3.1 Process

U&E presents five steps to identify customer needs [1, p.75] and they will be used as a guideline in this report:

1. Gather raw data from customers
2. Interpret the raw data in terms of customer needs
3. Organize the needs into a hierarchy of primary, secondary and (if necessary) tertiary needs.
4. Establish the relative importance of the needs
5. Reflect on the results and the process

Research by Hauser and Griffin [3], referenced in the U&E book [1, p. 77], compares focus groups and interviews as data collection methods, two very commonly used. The study recommends interviews as a primary data collection method. In this thesis, interviews have been chosen to collect customer needs. It is a very viable option and highly suitable for this project. From interviews personal opinions and the possibility are received to have an interactive dialog between developer and customer. Viewing the product through their eyes is definitely helpful. A focus group would make the participants think more or less the same in the end and that wouldn't give as good variety in customer needs. The product is new to the market and could, therefore, be difficult to find needs through groups and discussions. If there is a person that knows more about similar products than others, the chances are high that the focus will be at that person, not proceeding into discussions and revelations of personal needs of the others.

Griffin and Hauser also addressed the number of interviewees that were needed for revealing the most of the customer needs. One study, referenced in the U&E book [1, p. 78], showed that 30 interviewees covered approximately 90 percent of the customer needs for picnic coolers. However, lead users can be a more efficient way to identify customer needs. According to von Hippel, referenced in the U&E book [1, p. 78], lead users are customers who can discover needs months or years before the majority [4]. They can articulate emerging needs because they already struggle with them or have found own solutions to meet their needs. Those needs can still be latent for the majority, which makes it very useful for developers designing new products. Therefore, lead users have been the main focus for identifying customer needs in this thesis. Regular customers can find it difficult to identify needs if they don't have distinct references and hands-on user experiences. The preferable characteristics are people who have a good sense of technology, interior, design, and possibly owning some smart home devices. The questions were asked to staff workers in the already visited stores because of their special expertise in consumer products and technology.

Since the product is part of the existing Animus Home platform the customers will automatically be those who have the Animus Heart in their homes. However, it has been given by the company that the new product is not as attractive for younger customers since they often live in smaller apartments or feel that they don't need a stationary place for the panel. They feel that their smart phones are enough for this purpose.

3.2 Gathering raw data

Data were received through interviews from potential customers and are later interpreted into customer needs.

3.2.1 Customers

The main customers are couples or families who lives in bigger houses, possibly a multi-storeyed house. A single control unit for the entire home, which can be used by anyone in the house, is the highest priority for these customers.

3.2.2 Interviews

The interviews consisted of a short discussion where the interviewees got to answer some questions that were prepared to identify customer needs. Notes were then taken and gathered for later analysis. The questions were built upon the main idea of the product, covering all major aspects. They were formed to exclude potential biased influence so that the interviewees could answer with their own thoughts. For this particular reason, it is important to be specifically aware of the formulation of the questions. Before the questions were asked, a short describing scenario were told. It contained a brief version of Animus Home's concept - to allow communication between smart home devices with the use of a CP. Moreover, preparing them for the proper mindset considering the upcoming questions. The questions can be seen below and the gathered answers are found in appendix B along with the described scenario.

1. **What would you expect from the product?**
   This questions is expected to give the first thoughts of the product and what expectations they have for it.
2. **Where would you place the product?**
   This question gives the interviewee thoughts about possible locations in the home, not implying on any specific place.
3. **How would you like the CP to be placed onto the product?**
   This question shows how simple the product needs to be. They can also inform about horizontal, vertical, rotational and/or angled placement of the CP.
4. **When would you need to use the product?**
   This question gives information about what environments and scenarios the product will be used in.
5. **Is the design important to you and how?**
   This question covers the importance of design and usability. The interviewees can come up with suggestions and what they consider is good design.
6. **How would you like to charge the CP?**
   This question gives information of what types of charging possibilities that are most appreciated by the users and in what way this would be used.

After the gathering of raw data, the needs were interpreted and the relative importance were established and listed. The hierarchical template list from U&E book was used as reference [1, Exhibit 5-8]. Similar needs were grouped and given a collective label in the interpreting stage. The questions from the interviews generated a lot of answers and needs. Many of those were similar and had to be interpreted to filter the list and summarize the needs. The needs were categorized depending on their relative importance. Those decisions were based on the frequency of similar answers from the customers and also through interpretation from the team. For example, answers from the design question like “important with design”, “black or white”, “fit my home”, “quality looking” and “slim and takes up less space” were interpreted as “modern and subtle”.

3.3 Interpreted needs

The DS can be placed anywhere in the home

1. *** The DS can be placed on a wall

2. ** The DS can be placed on a horizontal flat surface

3. *! The DS can be placed on a fridge-freezer

The DS is prefered to be in central places

4. *** The DS can be placed in the hallway or living room

5. ** The DS can be placed in the bedroom or kitchen

6. **! The DS is placed in rooms where people gets closer to the walls

The CP is placed very easily on the DS

7. *** The CP is placed quickly and effortlessly on the DS

8. *** The DS holds the CP in a secure and robust way while docked

9. ** The DS guides the CP on to the correct position

10. * The DS allows the CP to be placed in both landscape and portrait position

11. **! The DS has an intuitive design on how to place the CP

The CP is removed very easily from the DS

12. *** The DS allows the CP to be removed without having to access small parts behind the CP

13. *** The DS can not be removed by accident

14. *** The DS stays in place when removing the CP

15. ** The CP can be removed quickly from the DS

16. **! The DS has an intuitive design on how to remove the CP

The DS has a stationary position in the home

17. *** The DS is used when the CP needs to be recharged or put away

18. *** The DS has a dedicated location in the home for anyone to access

19. ** The DS is used when the CP is in place and when the user makes short commands or quick overviews of the system

20. **! The DS has a call/response-function if the CP is lost somewhere in the home.

The DS looks modern and subtle

21. *** The DS blends in well with the surrounding environment

22. *** The DS expresses great quality

23. ** The DS is slim and doesn’t take much space

24. * The DS comes in different materials and colors

25. *! The DS is dirt repellent

26. **! The DS doesn’t express that something is missing

The DS is designed to be user friendly

27. *** The DS is grip friendly

28. *** The DS is easy to install on the wall

29. *** The DS stays in place when used on a flat surface

30. *! The DS can be slightly angled to fit different lengthened persons

31. **! The DS gives feedback when the CP is placed and removed

The DS provides easy charging for the CP

32. *** The CP is connected to the DS for charging without a cord

33. *** The DS gets its power through regular 230V power outlets

34. *! The DS indicates when the CP is charging and fully charged

3.4 Reflections

Since people have different taste and different ways of living we are satisfied with our varied choice of interviewees. Finding the customer needs with such a varied type of people gave us a broader view and every labeled group of needs covered at least one latent need, which is a good indication. The focus was on finding lead users, which is probably why so many latent needs were discovered. These needs are highly valued for the continued development of the product.

Feedback sessions of the final concept with lead users were expected to be performed by the development team, but got restricted by the company because of secrecy reasons. The company themselves may perform this later.

There are no big surprises from the customer need benchmarking. Some things that the development team haven't consider or received from the company have appeared during the interviews and will help the team in the development process. For example one interviewee really wanted to be able to put the CP on a fridge-freezer, or that we realized the importance of wireless charging. Another interesting need is that customers want the DS to be stationary but shows interest to use it or the CP in more rooms.

Overall, the team is satisfied with the results in this step. There could be more interviewees to get a wider perspective. However, homeowners are a very generic category of customers. For this thesis, the chosen customers with their experiences and with the focus on lead users are considered sufficient enough. A more thorough identification of customer needs could identify and categorize more customer segments, increasing number of interviewees and divide user experiences into relative importance. At this point no further follow-ups are necessary. The gathered customer needs data are considered sufficient enough to proceed to the next step.

4 Establish target specifications

In order to penetrate a market that is already provided by working solutions, it is required to set new and better specifications. Target specifications are goals for the development team. It sets guidelines for creating a market competitive product. However, the products in the benchmark are mostly products outside the home automation market which, instead, contributes with an interesting feature. There aren't so many competitive products with the same application, which makes the target specifications less crucial for direct comparison with the final concept. Instead, they work as a guideline and an overview of other existing solutions with their features. Later, the specifications for the final concept are added to compare them with the marginal and ideal values that these first specifications bring.

The process that will be followed is described in U&E [1, p. 95].

1. Prepare the list of metrics

2. Collect competitive benchmarking information

3. Set ideal and marginally acceptable target values

4. Reflect on the results and the process.

4.1 Prepare list of metrics

A list is prepared for showing the relative importance of each metric and also the units for the metric. This list becomes center for the relationship between needs and metrics. Every customer need corresponds to a single metric. The same list is used for the competitive benchmarking chart and is seen in table 4.1.

4.2 Collect competitive benchmarking information

Competitive benchmarking is important for understanding competitive products and becomes the base of understanding the market. A proper benchmarking chart will give the development team valuable information for the upcoming development process. Found in table 4.1 is the competitive benchmarking chart for this product.

Table 4.1 Competitive benchmarking chart.

Metric No.	***Need No.***	***Metric***	***Importance***	***Units***	*Quell & Co Spool Dock*	*Nest Thermostat*	*NuBryte Control Panel*	*Apple Elevation Lab Nightstand*	*Apple Twelve south Compass stand*	*Gigaset C430*	*Smartphone holder with ball joint*	*Vogel TMS RingO*	*König Unive-rsal stand*	*IKEA Induction charger*	***Marginal Value***	***Ideal Value***
1	1,2,3 ,4,5 6,18	Placement	5	List [a]	Table	Wall	Table	Table	Table	Table, Wall	Table, Window	Wall	Table, Hang on a hook	Table	Wall, Table	All
2	7,8,1 7 31	Steps to dock	5	Amount	1	-	2	1	1	1	1	1	3	1	2	1
3	8,19	How easy it is to tip CP from DS	4	Subj.	4	1	1	4	4	4	3	3	1	5	3	1
4	8	Weight of DS	2	g	900	244	370	88	230	200	120	80	750	300	600	200
5	7,9,1 0	CP insertion angles (alpha/ beta symmetry*)	4	°deg/ °deg [b]	180/360	-	360/360	180/360	360/90	360/360	360/0	360/0	360/90	180/0	360/360	180/0
6	8,13	Locks CP	5	Binary	Pass	Pass	Pass	Fail	Fail	Fail	Fail	Pass	Pass	Fail	Pass	Pass
7	9,17, 31	Guides CP to place	4	Binary	Fail	-	Pass	Pass	Pass	Pass	Fail	Pass	Pass	Fail	Fail	Pass

8	15,12,16	Removing the CP from the DS	5	s	1	-	1	1	<1	<1	1	2	3	<1	3	<1
9	11,16	How many tries it takes to remove the CP for the first time	5	Amount	1	-	1	1	1	1	1	2	1	1	2	1
10	13,14,19	How easy it is to accidently remove CP from DS	3	Subj.	-	1	1	-	-	2	5	3	-	-	3	1
11	19,29	How easy it is to move the DS on a flat surface when the CP is docked and in use	4	Subj	3	-	-	3	3	3	2	-	3	3	3	1
12	23,24	Dimensions (width/ height/ depth)	2	mm/mm/ mm	87/87/25	84/84/31	133/121/ 59	42/56/55	30/180/ 12,5	89/96/ 107	60/60/80	40/40/ 32,5	140/200 /60	130/130/ 20	100/100/ 100	< 100/ 100/ 100
13	20	Call/response function	4	Binary	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Pass

14	22,25,27	Material	5	List [c]	Wood, Wool, Plastic	Metal, Glass	Plastic	Plastic	Steel, Silicone	Plastic	Plastic, Silicone	Metal, Plastic	Plastic	Wood, Plastic	Plastic	All
15	21,22	Color	5	List [d]	White, Grey, Maple	Black, Silver	White	White	Black	Black	Black	Black, Silver	Black	White	White	All
16	30	Angled	2	/°deg	17	0	0	10	37	10	10-170	0	15-90	-	0	0-60
17	32,33,34	Charging	5	List	Cord	Battery	From switch panels	Wireless	-	Conne-ction points	-	-	-	Wireless	Cord	Wire-less
18	26	Expresses no missing parts	4	Subj.	4	5	5	4	1	1	1	4	1	4	2	5
19	28	Steps to install on wall	2	Amount	-	>5	>5	-	-	3	1	4	2	-	4	1

[a] List consists of: Any regular interior wall and all solid interior horizontal flat surfaces

[b] Explains symmetry for insertion of parts [5].

[c] List consists of: Plastic, Metal, Wood, Textile, Glass, Silicone and Rubber

[d] List consists of: All possible colors from the CMYK color model

4.3 Set ideal and marginally acceptable target values

The last step is to take all of the available information from the benchmarking to set target values for the metrics. These are presented in table 4.1 as well and will be guidelines for the development of the concepts. The ideal values are based on the best results from the competitive benchmarking and the marginal values are minimally accepted values based on a lower average of the benchmarked products.

4.4 Reflections

Establishing target specifications gave the development team a great starting point for the continued development of the product. Target values are for the most estimations set through team consensus. Some metrics are difficult to judge and measure, especially when there only are none or minor product specifications available.

It is important to remember that this product is a complement of another, the Animus Heart gateway. There is already a market for it and this product will follow in the same channels. This means that the development team focuses much of the development for the already existing concept. Key things to have in consideration are e.g. the product is used for home automation, it should fit the home environment and it becomes the center of the smart home. This kind of target specifications probably suits better for comparison with existing products within the same market. It is easier to understand how to penetrate the market by analyzing competitors’ products and draw conclusions from that. However, the product concept is new and the market is young which makes all kind of different inputs from existing solutions helpful.

5 Generate product concepts

The next step in the concept development process is the concept generation phase. The first steps, identifying customer needs and establishing target specification, have provided sufficient material to continue with concept generation. Moreover, a lot of needs have been identified ranging from tertiary to primary along with some latent ones.

5.1 Evaluation criteria

A benchmark with existing solutions has been evaluated to get a proper understanding of the market, references to the target specification and ideas for the generation process such as needs they cover and miss out. Before the generation process starts, the evaluation criteria for the concept selection are decided. This is to prevent the criteria for being biased according to the concepts that is about to be generated. The following criteria have been chosen from the results of previous steps. However, they are also formed from the guidelines from the company, Animus Home, which can be shown in the mission statement.

- Ease of mount/dismount
- Ease of placement
- Charging possibilities
- Intuitive design
- Designed for home environment
- Safety

Ease of mount/dismount - The possibilities to mount/dismount the DS on the wall and mount/dismount the CP on the DS will be evaluated in this criterion.

Ease of placement - This criterion evaluates the solution for the ease of placement on a flat surface in an angled position.

Charging possibilities - Different charging possibilities and the ease of charging will be evaluated in this criterion.

Intuitive design - This criterion evaluates how intuitive the design is for the user. Ease of mount/dismount covers the ease of the actual motion or steps whilst the intuitive design tells how easy or difficult it is to understand the way to do it.

Designed for home environment - This criterion evaluates how well the design fits in a home environment of the intended user.

Safety - This criterion evaluates the safety aspect of the design. It covers how stable the DS and/or CP are, mounted, standing or charging, and how they respond to accidental use.

These criteria are the foundation for the concept selection later in the process. For now, they are set and will not be used during the steps until that point.

5.2 Process

In this thesis, U&E five-step method [1, Exhibit 7-3] is used as a template for the generation process. It breaks complex problems into simpler subproblems, identifies concepts through internal and external search procedures, explores classification and combination of concepts and ends with a reflection. Figure 5.1 below illustrates the five-step method.

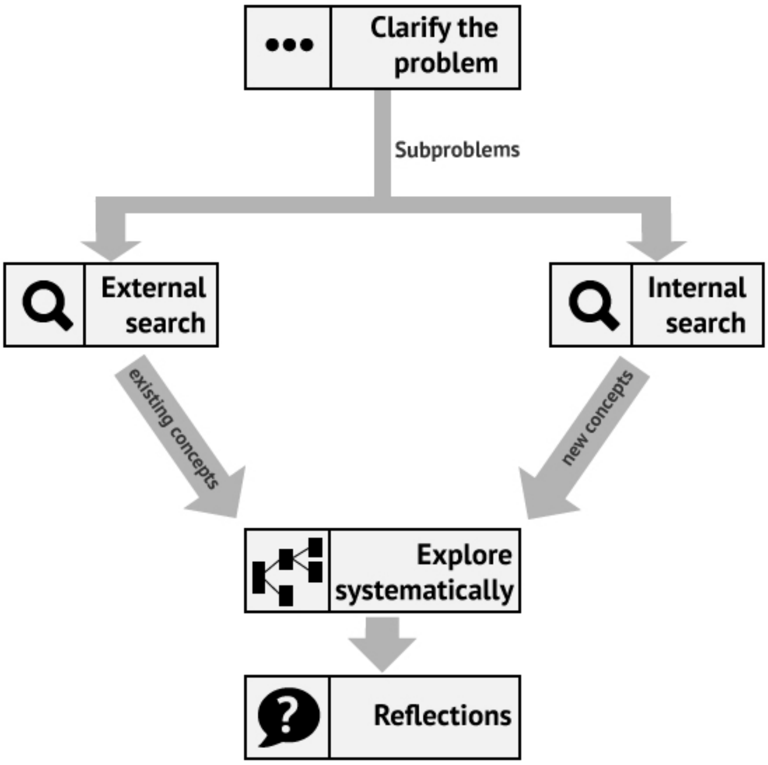

Figure 5.1 Five step method for concept generation.

5.3 Step One: Clarify the problem

Most of the product development projects consist of a complex problem that can be decomposed into simpler, more intelligible, subproblems. By doing this it becomes easier to comprehend the complex problem and find solution fragments that can be combined into one final solution.

Such decomposition was performed by the development team in this project as well. The subproblems are listed below and were decided through team discussions with previous basis in consideration.

Subproblem 1: Placement - Placing the CP on flat horizontal surfaces

Subproblem 2: Energy - What energy solutions are there?

Subproblem 3: Shape - Discreet and attractive design

Subproblem 4: Docking & locking - Securing the CP onto correct position on DS

5.4 Step Two: Search Externally

This step aims to look for existing solutions to the identified subproblems. External search occurs more or less during the whole concept development process, here done systematically to get an overview of all the possible solutions. Since it is much cheaper to implement existing solutions rather than developing new ones, this is a great way to allow the development team to focus their energy on the most critical subproblems. Having done an external analysis like this also allows the development team to find new combinations with conventional solutions. The external analysis for this project is summarized below.

A brief search on the patent database Espacenet, found at the website https://worldwide.espacenet.com/?locale=se_SE, was executed to see if there is any patent worth looking any deeper into. The website is recommended to use by the Swedish Patent and Registration Office, PRV, to find patents in the whole world. The following search words were investigated:

"Docking station for home device", no relevant results

"Smart home docking station", no relevant results

"Smart mount", no relevant results

"Smart home control panel", no relevant results

No further investigation of patents was made once these were executed because the team didn't find any value from it.

A search on solutions with some kind of relation to the overall problem was also made. The search was mostly focused on single subproblems, not the overall problem.

A lot of inspiration was received just by entering an electronics store and finding solutions for the subproblems. By looking at devices and products for other purposes, but with some feature applicable to this product, the team could generate ideas. Ideas as how the device could stand on a flat surface, different docking alternatives and design features.

To find inspiration about what charging possibilities there are, we made a search of all kinds of electronics devices that requires charging somehow; smart phone, electronic toothbrush, office phones, smart watch, smart switches, smoke detectors, digital frames etc. We came up with a couple of charging possibilities like; wireless charging, touch pins, in wall wiring, replaceable batteries or power cord.

One clear realization regarding the design features was that clean and simple shapes appeared the most. The materials are for the most attractive and give a feel of premium quality.

When it comes to mounting solutions the search was focused to wall mounted devices like; smart thermostats, light switches, touchpad wall mounts etc. Characteristics of magnet are quite interesting and they can be used in many different ways for different applications. Some kind of magnetic locking was therefore thought of early on. Nevertheless, the development team also made searches on other types of locking mechanisms and found a couple of interesting types of locking systems that could also work for this project; snap-locking, friction, screw and velcro straps.

5.5 Step Three: Search Internally

At first, the team members did idea generations individually. After that, a group discussion with more concept ideas and also combinations of already generated concept ideas. The individual concept generation was made to avoid similar thinking and to receive a large variety of the concepts.

5.6 Step Four: Explore Systematically

This section lists all generated concepts, received internally and externally, into their corresponding subproblem. They don’t count as complete concepts, but when combined, a complete concept is created. The complete concepts are generated with help from a combination tree in the next step, which later on will be evaluated.

Solutions to Subproblem of placement:

- Ball joint to angle the CP
- Foot that flips out in different positions to get the wanted angle
- A stand that flips out in a certain angle
- Place the CP on an included static support
- A rotational stand so that the CP can be placed horizontally and vertically
- Extendable metal strip that the CP can rest on
- Magnetic surface

Solutions to Subproblem of shape:

- Rectangular
- Cylinder
- Triangle
- Dome shaped circle
- Simple straight bar
- L-shaped
- U-shaped compartment
- Ring
- Knob

Solutions to Subproblem of charging:

- Power cord
- Induction
- Contact pins

Solutions to Subproblem of docking:

- Magnets
- Snap lock
- Hanging on something
- Holding clamp
- Rest freely on something with its own weight
- Rotational docking

5.6.1 Concept combination tree

Dividing the project into more intelligible subproblems allowed the team to generate ideas more easily for the specific subproblems. However, a concept combination tree had to be implemented to receive complete concept ideas. A combination tree gives the development team a great overview over the solution fragments and by combining these, full concepts will be generated. It consists of four columns, listing solution fragments under every subproblems. Part of the combination tree used for this project is shown in figure 5.2 with an illustrated example of how the combinations are done.

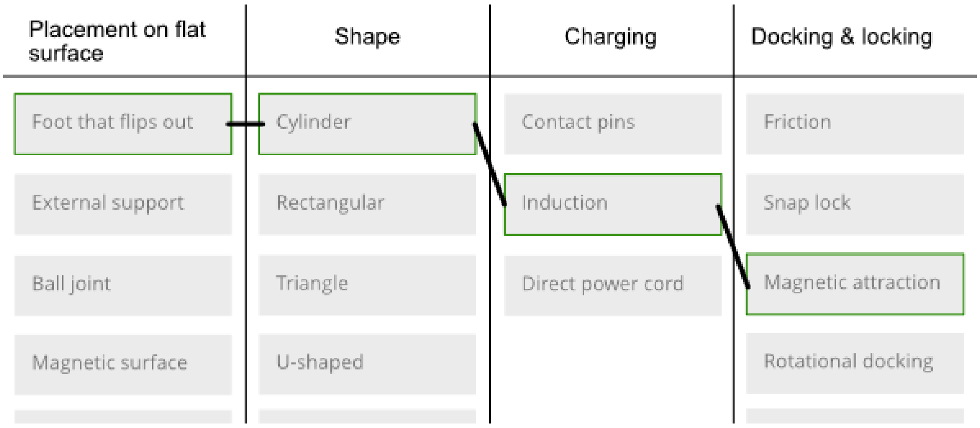

Figure 5.2 Concept combination example showing the combination of concept PUCK.

Same procedure was performed until the team was satisfied with the solutions received from it. The results and combinations are shown below:

Table 5.1 Results from concept combination.

Concept name	***Subproblems***			
	Placement on flat surface	***Shape***	***Charging***	***Docking and locking***
A. SNAPPER	Ball joint foot	U-shaped compartment	Contact pins	Snaps in place
B. PUCK	Foot in certain angle	Cylinder	Induction	Magnets
C. HOOK	Foot in different positions	Simple straight bar	Contact pins	Hanging on something
D. MAGNETIC PLATE	Magnetic surface	Rectangle	Induction	Magnets
E RAIL	Foot in certain angle	Simple straight bar	Contact pins	Hanging on something
F. SCREW	Foot in certain angle	Cylinder	Induction	Rotational

A. SNAPPER

Snapper is a concept using some sort of snap function for locking the CP in place. It consists of a rectangular plate, as shown in figure 5.3, mounted on the wall with two extended bars on the bottom and top. The CP is mounted by placing it on the lower bar and then clicking it into position, holding it with help from the upper bar. The plate has two contact pins on the bottom bar that connects to the CP allowing charging. When CP is placed on flat surfaces it stands on a small foot with a ball joint, see figure 5.4.

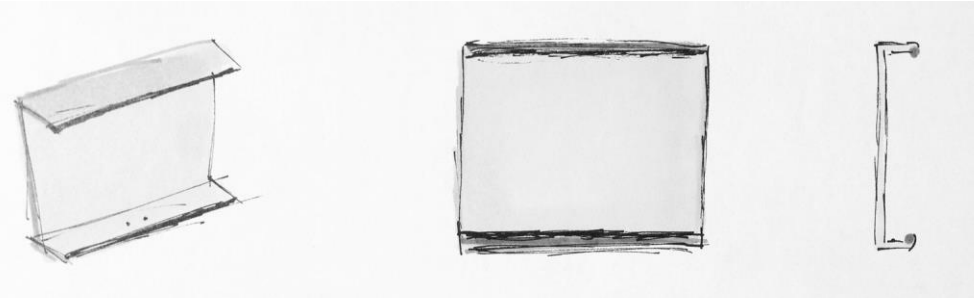

Figure 5.3 Concept drawing of SNAPPER

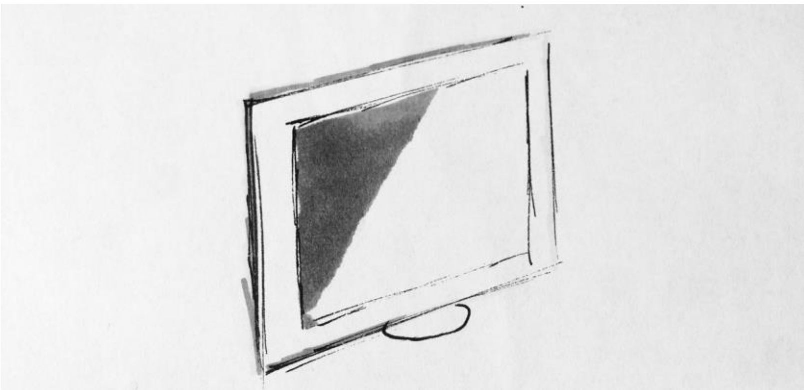

Figure 5.4 CP standing on a flat horizontal surface with foot.

B. PUCK

Puck is a concept combining wireless charging with magnetic click-function for locking the CP in place. The puck concept consists of a cylindrical part that is mounted on the wall, as shown in figure 5.5, and holds all the electronic, including a transmitter coil for wireless charging. Moreover, there is another part integrated in the CP shaped as a cylindrical ring holding the magnets and also the receiver coil of the wireless charging. The CP also has an integrated support that flips out when wanted on a table, as illustrated in figure 5.6.

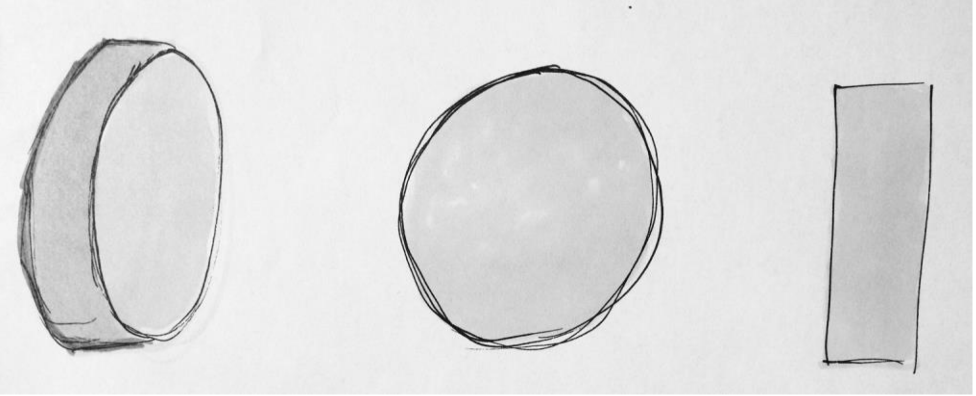

Figure 5.5 Concept drawings on PUCK.

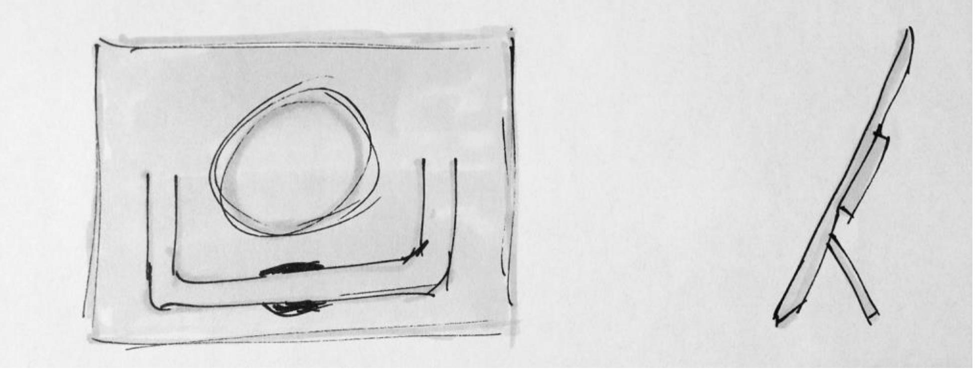

Figure 5.6 Concept PUCK backside view (left) and stading on a flat horisontal surface (right).

C. HOOK

Hook is a concept consisting of a part mounted the wall that has a compartment (figure 5.7) and the CP in turn has a bar that fits into that compartment (figure 5.8). It slides into the compartment and gives charging through three contact pins connecting on the bottom of the compartment. The bar also works as a stand for the CP when placed on a table. It can give angle in three positions from its hinge with locking.

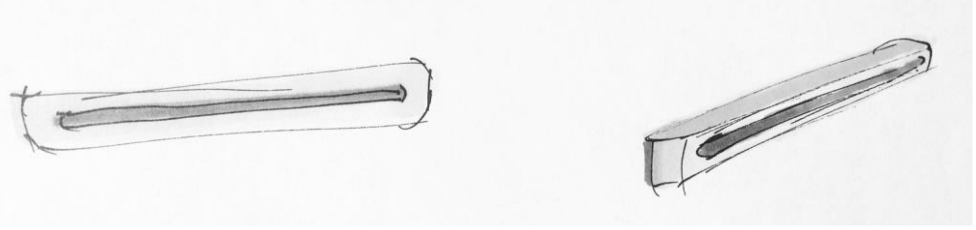

Figure 5.7 Concept drawings on HOOK.

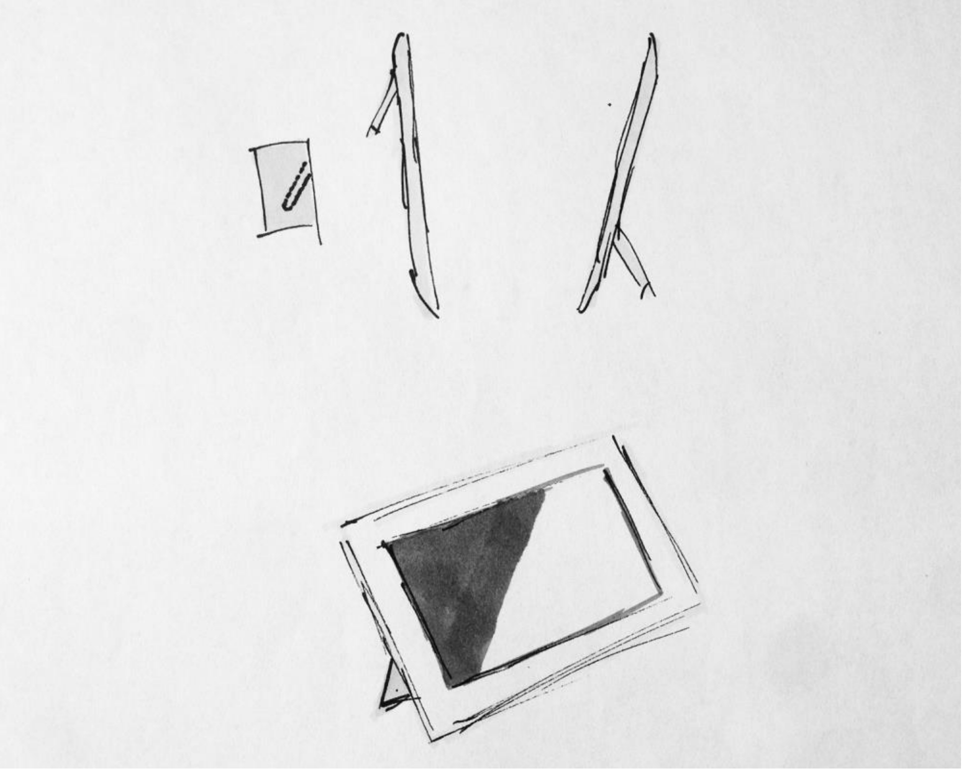

Figure 5.8 Side view of the CP getting docked onto the wall bar (upper left) and CP standing on a flat surface with foot (bottom image and upper right).

D. MAGNETIC PLATE

Magnetic plate is a concept with a completely magnetic solution that also allows the CP to be placed on fridges, see figure 5.10. It consists of two parts, a magnetic plate (figure 5.9) that is placed on the wall and another magnetic plate which is placed on the back of the CP. The plates attract each other when mounted and locks the CP in the right position. Charging is received wirelessly between one transmitter coil on the wall-plate and one receiver coil on the CP.

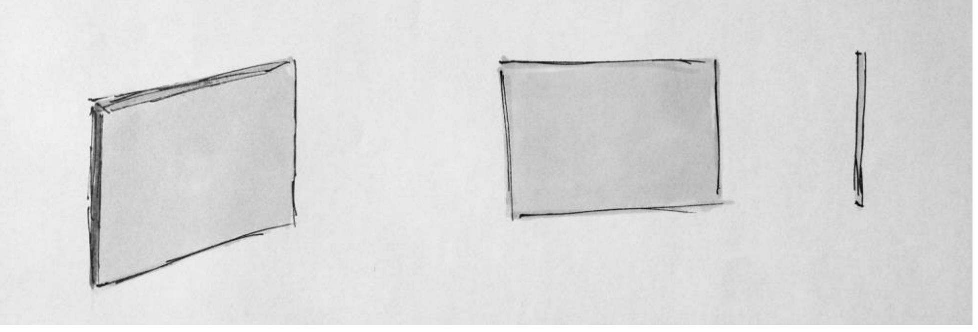

Figure 5.9 Concept drawings on MAGNETIC PLATE.

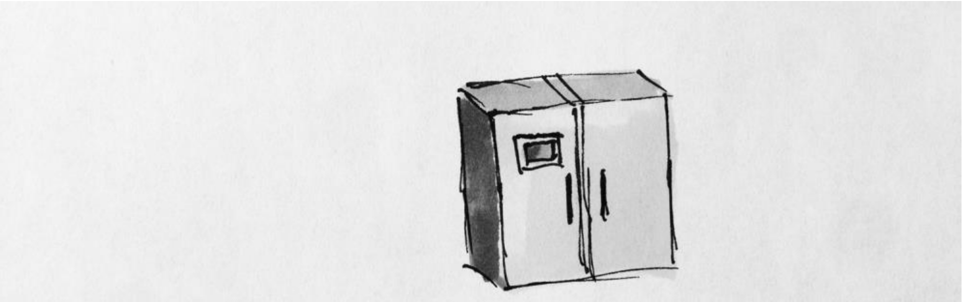

Figure 5.10 Concept MAGNETIC PLATE placed on a fridge.

E. RAIL

Rail is similar to the hook, existing of two parts. One on the wall, which is the rail (figure 5.10) and one on the CP, which is the track (figure 5.11). The CP slides onto the rail and the charging is received from contact pins on the sides of the rail. When CP is used on flat surfaces it can unlock the track and use is as a foot for support.

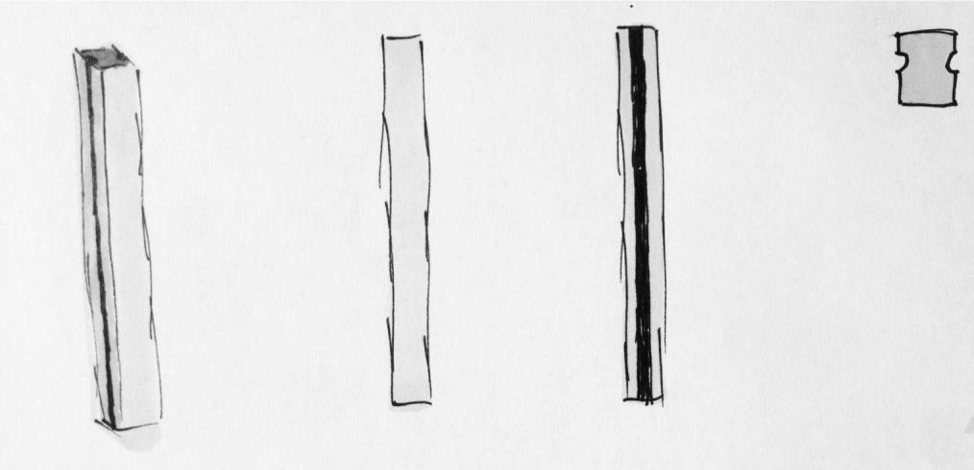

Figure 5.10 Views of concept RAIL on wall and top view (top right).

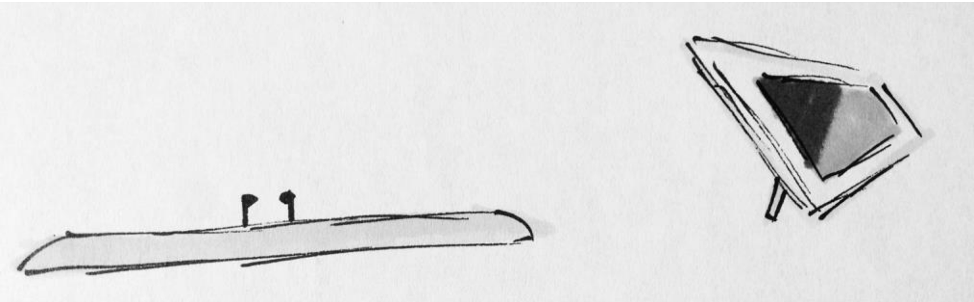

Figure 5.11 Top view of CP (left) and CP on a flat surface (right).

F. SCREW

Screw requires the user to screw the CP in position. It has a circular shape, almost like the puck, and tracks around it to guide the CP in position as seen in figure 5.12. On the CP there are pins sticking out which fits with the tracks. It charges through induction charging which has a transmitter on the cylinder and the receiver on the CP. To place the CP on a flat surface it uses an integrated foot, same as in concept Puck, see figure 5.6.

Figure 5.12 Concept drawings on SCREW.

5.7 Step five: Reflections

Six concepts were generated, including both unique and similar features. This way, the concepts are not only unique or similar which results in a complete mix of concepts. For instance, puck and screw are similar but have different mounting procedures and safety aspects, while hook and rail or similar in their shape and charging solutions. However, these two pairs against each other are very different. A decision was made to focus on a smaller amount of concepts that are more detailed from the beginning. With the combination tree, a lot of concepts can be created. Instead, the concept selection has already started by narrowing down the concepts to substantial concepts that are considered sufficient enough to proceed with, which will make the upcoming concept selection less overwhelming.

6 Select product concept

In previous stages in the process the development team have identified a good list of customer needs and in response to these, generated several working concepts. This chapter regards the evaluation of the generated concepts with respect to the customer needs and other criteria.

6.1 Evaluation process

The evaluation method was inspired from U&E concept selection method [1, Chapter 8, pp. 143-164] and begins with preparing the selection matrix. Concepts are expressed in separate columns and evaluation criteria listed in rows. Evaluation criteria are then weighted of their importance, which is determined subjectively by team consensus. The following criteria were considered in this evaluation and were described more thoroughly in chapter 5.1:

- Ease of mount/dismount
- Ease of placement
- Charging possibilities
- Intuitive design
- Designed for home environment
- Safety

6.2 Concept scoring

After having the matrix ready, scoring is executed by the team. Firstly, a reference concept was decided. This will become a reference for all the other concepts in the evaluation and gets a rating of 3 in every criterion. For this project concept Snapper is defined as reference.

Secondly, rating the concepts was performed. The rating is set between a scale of 1-5 and the relative performance is defined, see table 6.1.

Table 6.1 Relative performance.

Rating	*Relative performance*
1	Much worse than reference
2	Worse than reference
3	Same as reference
4	Better than reference
5	Much better than reference

Once the ratings are entered for each concept, scores are calculated by multiplying the raw scores with the criteria weights as described in formula 6.1. Then the total scores for each concept are calculated by summarizing all the weighted scores with the following equation [1, p. 156]:

$$S_j = \sum_{i=1}^{n} r_{ij} w_i \qquad (6.1)$$

Where

r_{ij} = raw rating of concept *j* for the *i*th criterion

w_i = weighting for *i*th criterion

n = number of criteria

S_j = total score for concept *j*

Lastly, every concept is given a rank corresponding to its total score.

Table 6.2 Concept scoring.

		A. SNAPPER (ref.)		B. PUCK		C. HOOK		D. MAGNETIC PLATE		E. RAIL		F. SCREW	
Selection Criteria	***Weight %***	***Rating***	***Weighted score***	***Rating***	***Weighted score***	***Rating***	***Weighted score***	***Rating***	***Weighted score***	***Rating***	***Weighted score***	***Rating***	***Weighted score***
Ease of mount and dismount	20	3	0.6	4	0.8	2	0.4	5	1	3	0.6	1	0.2
Ease of placement	5	3	0.15	3	0.15	3	0.15	1	0.05	3	0.15	3	0.15
Charging possibilities	20	3	0.6	3	0.6	3	0.6	3	0.6	3	0.6	3	0.6
Intuitive design	10	3	0.3	4	0.4	2	0.2	5	0.5	2	0.2	2	0.2
Designed for home environment	25	3	0.75	5	1.25	4	1	5	1.25	4	1	4	1
Safety	20	3	0.6	3	0.6	2	0.4	1	0.2	4	0.8	5	1
Total score			3		3.8		2.75		3.6		3.35		3.15
Rank			6		1		5		2		3		4
Continue?			No		Develop [a]		No		No		No		No

[a] This concept was chosen also by the company to continue with.

Comments on the concept scoring:

Ease of mount - The magnetic plate is by far the easiest one to mount/dismount. The screw is a bit awkward mount because of the threads and lack of sight. The hook is difficult to mount because it is difficult to see where to put when the CP is in front of the user.

Ease of placement - All concepts got ranked the same except the magnetic plate. It doesn't have a stand and can only be placed flat and not angled.

Charging possibilities - They all have wireless charging, which is ranked in the same way.

Intuitive design - When the CP is mounted, it is difficult to know exactly how to remove it. The design encourages pulling it towards the user, which only the Puck, Magnetic plate and partially the Snapper can do. The Magnetic plate can be removed in any possible direction and the Puck has less options. The criterion also addresses how easy it is to understand how to mount it, but it doesn't really change the outcome of the current score.

Designed for home environment - Most of the concepts are clean and blend well into a home environment. The Snapper looks bulky compared to the others. The Puck and Magnetic plate looks best. The threads on the Screw looks worse compared to the smooth surface on the Puck.

Safety - The Screw is the only one that is definitely locked in place and the Rail is not far away. The Hook is not that securely attached and the Magnetic plate can be accidentally removed in any possible direction.

6.3 Final concept selection

As seen in table 6.2 concept Puck is ranked the best and became the one to proceed with. The concept was elaborated internally within the team to specify more features for the next step, which is making a prototype. The final description of the product concept became the following:

Concept Puck consists of two units. One is the actual puck, which is supposed to be installed on a wall with two screws. There will be a spirit level somewhere to make the installation easier. The Puck has three key features. One is charging wirelessly, which means that some sort of wireless charging coil needs to be implemented. Secondly, some sort of interaction feature with the user is needed. For this the team came up with the idea to have a backlight on the Puck that indicates status of the CP and notifies if something is wrong. A button to turn this feature off was also decided to be implemented with the reason that everyone don’t like having a flashing light in their home, especially at night. Lastly, the Puck will have some sort of locking mechanism with magnets positioned in a way where 90 degree locking is received. This entire means that a lot of electronics and other components need to fit the Puck, which is a clear challenge for the team henceforth.

The other part of the concept acts on the CP. The CP is already defined in the mission statement to be a 7” Nexus touch pad. The second part concept Puck was therefore customized to fit this specific touchpad. A couple of features needed to be considered for customizing the second part to the CP. One is adding a wireless charging receiver and connecting it to the actual CP. Another is to solve the magnetic locking so that it works well with the puck. Lastly, the CP needs some kind of support when placed on a flat surface and for this the team decided to integrate a foot that flips out when needed.

All the concepts were presented to the company [6]. In this presentation, the team was advised to move on with development of concept Puck, as the results from the concept scoring also showed.

6.4 Reflections

As mentioned in the reflection in the concept generation phase, the concept selection started in that phase. Concept screening, which is a common selection step before concept scoring, was left out. Instead, a direct evaluation was made with the combination tree. Concept screening is a simple way of narrowing down and evaluating the concepts, which can result in combinations between them. However, the combinations of the subproblems’ solutions were already made during the generation phase. The results from that phase were considered sufficient enough for concept scoring.

7 Concept testing

The final concept had to be tested before the prototype got 3D-printed. It contains electronics that requires testing to know if the concept is feasible to continue with. Otherwise, it would be costly to print something and then have to redo it because the components didn't work or fit in the construction. However, it is important to expect at least one iteration of the prototype because everything gets more distinct, substantial and visually aiding from the first prototype. The main purpose is to develop a fully functional prototype that is ready to use.

7.1 Wireless charging

To integrate the wanted features, some electronic components were needed for the prototype. Many of the components were bought at Electrokit, a local electronics-store. For the induction charging system, a wireless charging module, also shown in figure 7.1, of 1A and 5V were used and was found on Electrokit is website [7]. Preferably, a more powerful charging module would be better but this will still be enough for proving the concept.

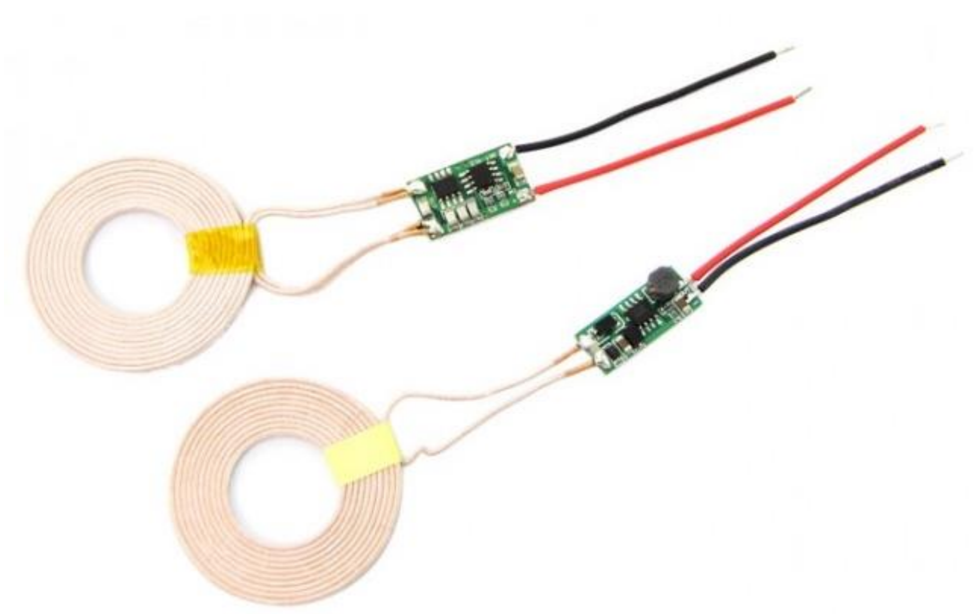

Figure 7.1 Wireless charging modules for prototype build [7].

To better understand the components and the wireless charging power system, some specific tests were performed. By giving it the max power supply (5V, 1A) to the transmitter and measuring the power output on the receiver with a digital multimeter resulted in a couple of conclusions:

The closer the coils were to each other the better the results were. This was tested by adding distances between the coils and then measuring the electric current going to the receiver, as seen in figure 7.2. Allowed distance for receiving wireless charging was, according to the tests, under 10mm, which matches the datasheet of the components. Results of the complete tests are compiled in figure 7.3.

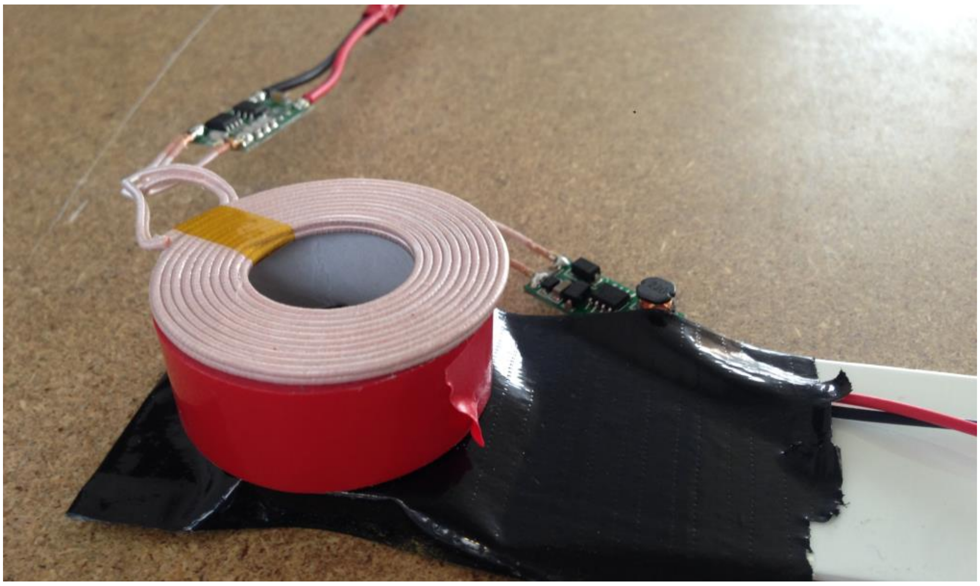

Figure 7.2 Checking the electric current with 10 mm distance between the coils.

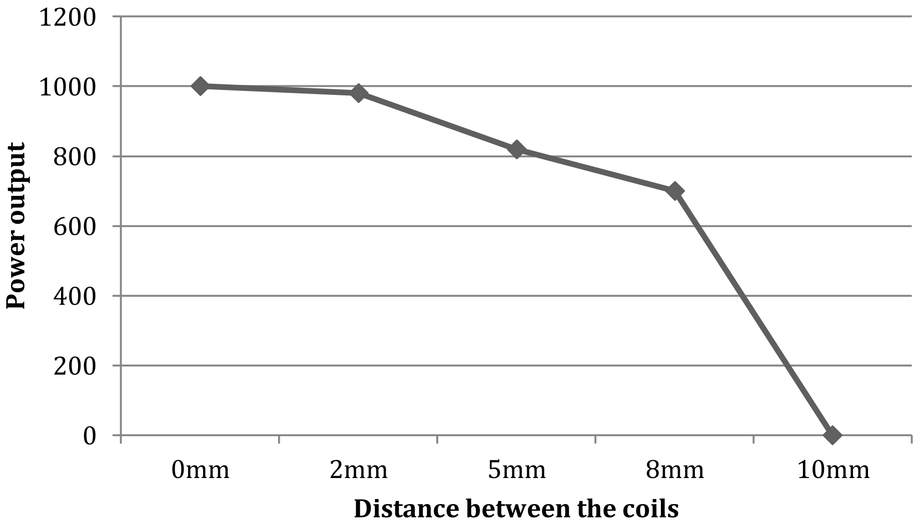

Figure 7.3 Graph showing power efficiency for the inductive transfer system depending on distance between the coils.

Magnets around and between the coils didn't affect the result. The concept includes magnets which makes it important to make sure that the magnets don't affect the magnetic field of the induction charging.

Metal plate between the coils affected the results a lot. There was no induction charging when having a metal plate between the transmitter and receiver coil. Other materials such as, plastic, wood and textile were also tested, as seen in figure 7.4, but didn’t affect the results. In conclusion, it has to do with the magnetic field that is created to give wireless charging. A metal plate intersects the magnetic field and the receiver is, therefore, not aligned anymore with the magnetic field from the transmitter.

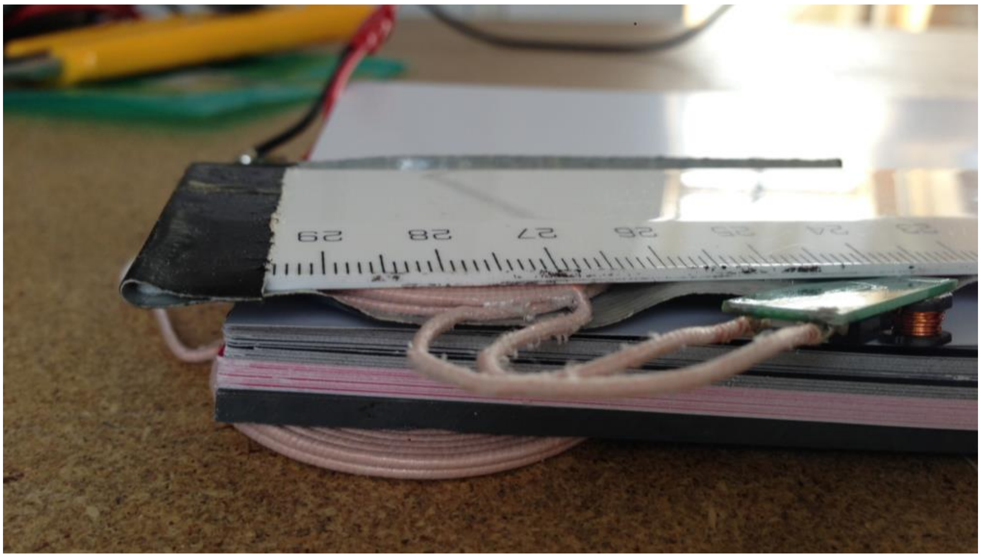

Figure 7.4 Trying out how different materials affects the power efficiency of the wireless charging.

Furthermore, the coils became hot when charging, which will later be measured more specifically.

Another test was performed to understand the wireless charging technology better. This time, a combination test was made between another wireless charging transmitter from IKEA [8] and the prototype component receiver, as demonstrated in figure 7.5. It resulted in no charging at all. In conclusion, the transmitter and receiver coils are almost invariably resonated. It is not possible to combine different kinds of transmitters and receivers.

Figure 7.5 Testing the prototype reciever with the wireless charger from IKEA and seen with the multimeter that there were little, or no, current flowing. (8mA)

7.2 Lighting

Since the decision about integrating wireless charging into the product, ways to indicate status and other notifications somehow were examined. Visual feedback (lighting) became therefore the best solution to this. A simple LED diode could be placed somewhere on the Puck but instead of that, an LED-ring as backlight behind the Puck was decided to be implemented. A more elegant LED solution suits the concept and customers needs better rather than a single diode. For that a NeoPixel ring with 16 RGB LED lights, seen in figure 7.6, was bought from Electrokit [9].

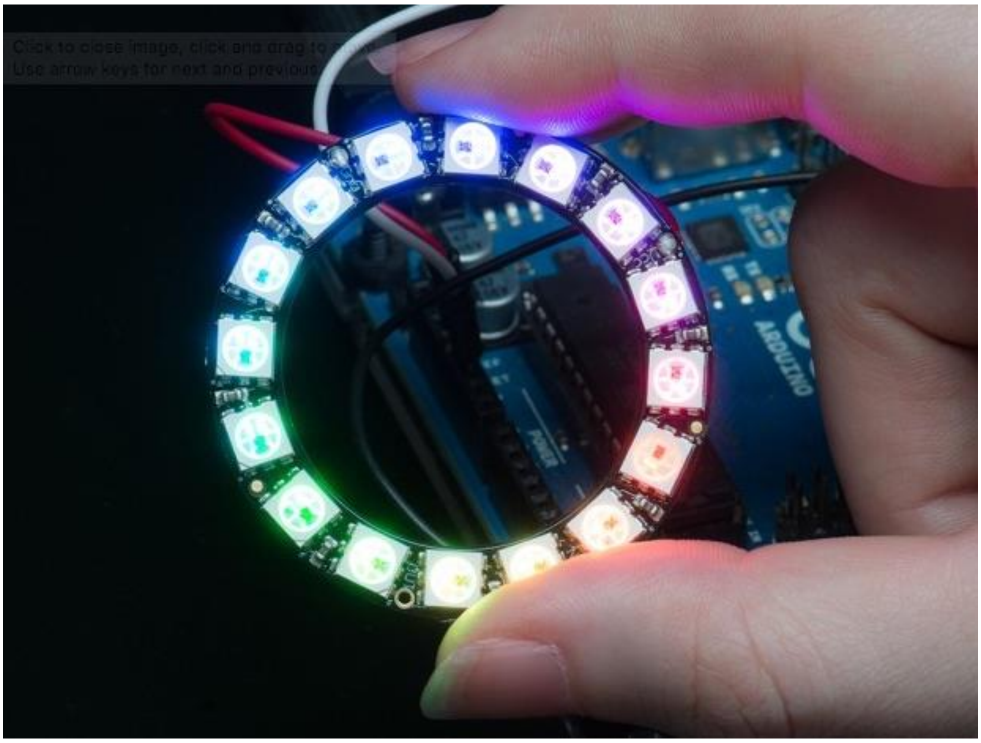

Figure 7.6 NeoPixel ring used for the backlighting. Image is from the Electrokit's website [9].

7.2.1 **Setup**

To control the lights, some sort of microcontroller was needed. To choose the most suitable one for the concept, the following criteria were crucial to make the right decision:

1. Easy programmable - The team's hardware-programing skills were limited and needed, therefore, a simple microcontroller for prototyping purposes.
2. Small - Since the Puck is very compact and small, a big component for controlling the lights couldn't fit there.

The most suitable microcontroller that was found was an Arduino Pro Mini [10]. No other programming device is needed except a regular computer and a free software for it. The microcontroller is very small, as seen in figure 7.7, and don't have any pre-added connectors, only pins to connect to. This means that a USB-connector is needed to be able to send code from the computer to the microcontroller. But, instead of adding a connector, the microcontroller was connected to a prototype-board with pre-added connectors.

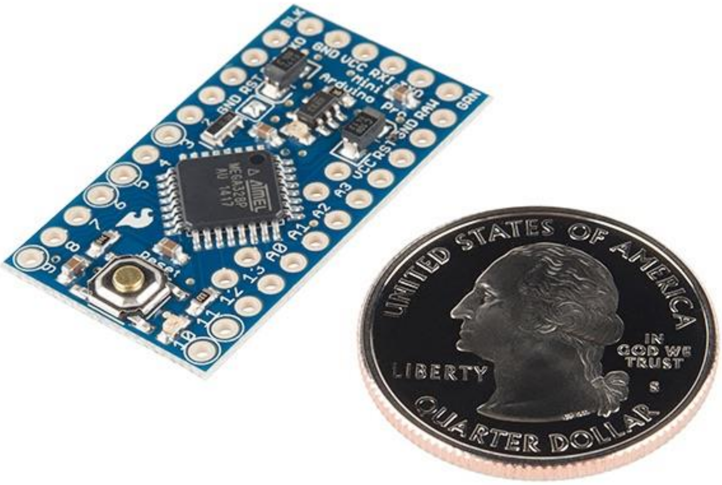

Figure 7.7 Arduino pro mini close to a quarter dollar coin. Image received from Sparkfun [11].

7.2.2 Wiring

The prototype-board was an Arduino Uno because it is compatible with the microcontroller and also has the same architecture. By connecting the Arduino ProMini to the Arduino Uno board, it can communicate through the Uno to the ProMini as shown in figure 7.8. To know how to connect this, a guide was used from Instructables [12] which is a website for Do-It-Yourself purposes.

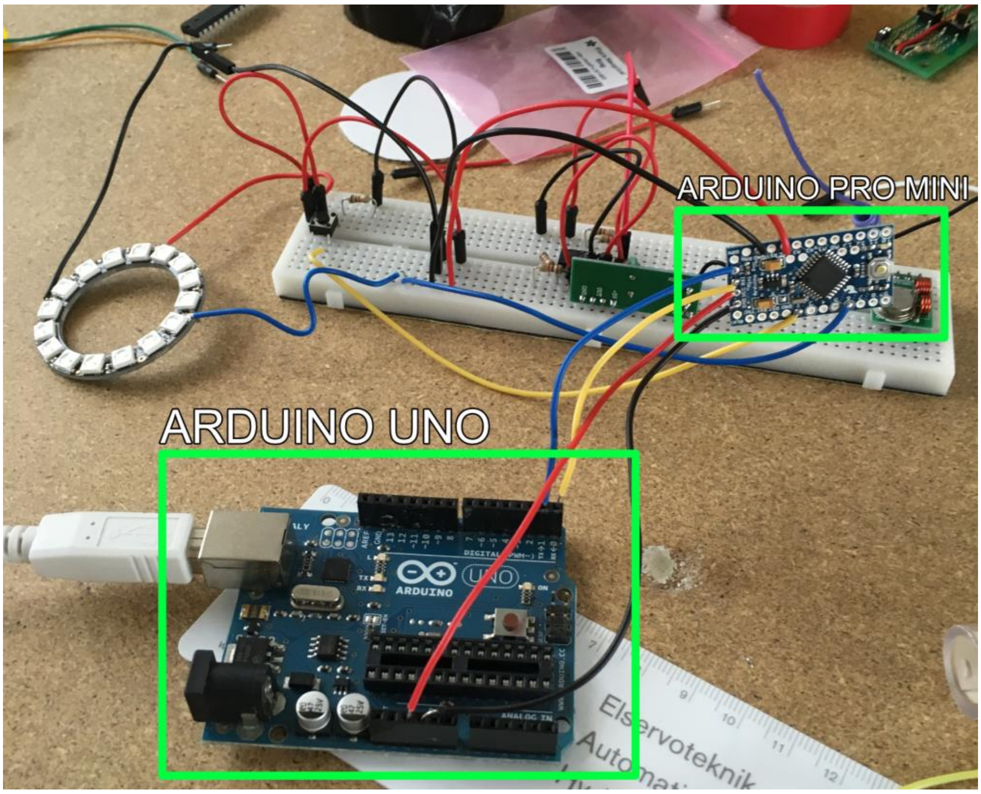

Figure 7.8 Connection of the Arduino Uno and the Arduino Pro Mini.

The wire-connections to the NeoPixel ring were done in the following way:

- "VCC" (5V power) is connected from the microcontroller to "PWR" on the NeoPixel ring
- "GND" (ground) is connected from the microcontroller to "GND" on the NeoPixel ring
- One of the digital pins on the microcontroller "Pin 6" (data) to the "Data In" on the NeoPixel ring.

The development team decided to include a push-button somewhere on the Puck. This was decided because of two reasons. One was that everyone isn't fond of having a light flashing in the home that they can't turn off. Secondly, from the user needs, some kind of call/response-function was also appreciated to be able to call for the CP when lost. When the button is pushed and held down for one second it will send a signal to the CP, which will start ringing to signalize where in the house it is.

The button is connected between the NeoPixel ring and the Arduino Pro Mini so when the button is pushed, only the power to the NeoPixel ring is turned on or off. It is protected with a resistor to prevent current overload.

The schematic for the NeoPixel ring, the Arduino Pro Mini and the button can be found in chapter 8, figure 8.33. The figure represents the final schematic for the Puck and, therefore, includes to connection between the mentioned components.

The power requirements for the charging components and the NeoPixel ring are the following:

- 5V and 1A to the wireless charging transmitter coil
- 5V and 1A to the NeoPixel ring

Therefore, a DC power supply of 5V and 2A was bought at Kjell&Co [13]. However, it was saved for the prototype testing where it connects to a DC-jack, which is explained later in this thesis.

7.2.3 Coding

The NeoPixel ring already has its own code library [14] for Arduino and was downloaded and used to understand how to control it.

The Arduino Uno board has a built in USB-connector, which makes it easy to code with any computer. For efficiency reasons, the code testing was all performed on the Arduino Uno until the wanted results were reached. The code was written in the Arduino software, downloaded from their website [15], and the code-language is merely a set of C/C++ functions. The complete code used for controlling this project's NeoPixel ring is attached in appendix C.

After a couple of iterations the development team were satisfied with the code and continued with transferring the code from the Arduino Uno to the Pro Mini. Once the code was transferred to the Pro Mini, the Uno was not needed anymore and was disconnected.

7.2.4 Results

Everything worked as intended. The NeoPixel ring could be turned on or off with the button. The code is stored in the Arduino Pro Mini and ready to power the NeoPixel ring in the prototype. The color of the backlight is coded to stay blue to match the company's profile.

7.3 Additional components

Two components, one spirit level and one DC-jack, were not concept tested. The development team decided to squeeze in a spirit level in the Puck to make the mounting of the Puck as simple and correct as possible. It needs to be in a straight position because of the alignment of the magnets. If not completely horizontal, the CP will be oblique when mounted on the DS because of the magnets. The mini spirit level that was used (A in figure 7.9) is taken from a bigger spirit level bar seen in figure 7.9.

Figure 7.9 The mini spirit level (A) inside a bigger spirit level bar.

The DC-jack was bought at Electrokit [16] to be able to convert the power from the power supply, mentioned earlier, to all electronic components. Before, and during the concept tests, other types of power supply sources were used to proof the concept. As long as the components work when powered, a newly bought DC power supply with a suitable DC-jack will not be a problem.

8 Prototyping

This chapter summarizes the prototyping phase where the team members gathers all the findings and puts them into one single product. Stretching all the way from paper mock-ups to 3D-printed full size parts.

8.1 Mock-up prototyping

After all the tests, different magnetic locking functions were examined. Ideas were generated from a playful brainstorming session where the development team could try out simple constructions with small Neodymium magnets (seen in figure 8.1) to create preferred magnetic fields. Basic understanding of magnets and their properties was sufficient to construct different magnetic locking mechanisms. To make magnets snap in certain locations and repel in others by just rotating the surface, were wanted properties. Neodymium magnets were used due to their powerful magnetic field despite their size.

Figure 8.1 Neodymium magnets close to a ruler indicating their size. Image reference [17]

The idea is to create attraction and repulsion on the same surface. Therefore, different constellations were tested to try to obtain the right feeling, as in guidance to get the right snap, and the desired locking mechanism. The magnets were placed on a flat surface in a specific pattern that created both attraction and repulsion, as seen in figure 8.2. Four magnets, facing the same side up, were used to allow ° rotation of the CP. As well, the CP has four magnets in the same pattern on the back that attracts the magnets on the flat surface. On the flat surface, the magnets were surrounded by magnets facing the opposite side up, creating a flat surface with both north and south side magnetic fields. However, after some concept testing, it didn't turn out as expected. Two flat surfaces with no slots or tracks made it difficult for the magnets to snap in the right place with all four magnets. It can easily snap onto only two of them without any visual notice and it is mainly because of the narrow magnet arrangement. Due to lack of space, the magnets need to be close to each other so that the puck doesn't get too wide. Therefore, it is difficult to know if the CP snaps to two or four magnets because the snap feedback is the same. It is also important to obtain the proper magnet lock to reduce the chances of an unwanted accident. Therefore, this concept was abandoned and a new one derived from it.

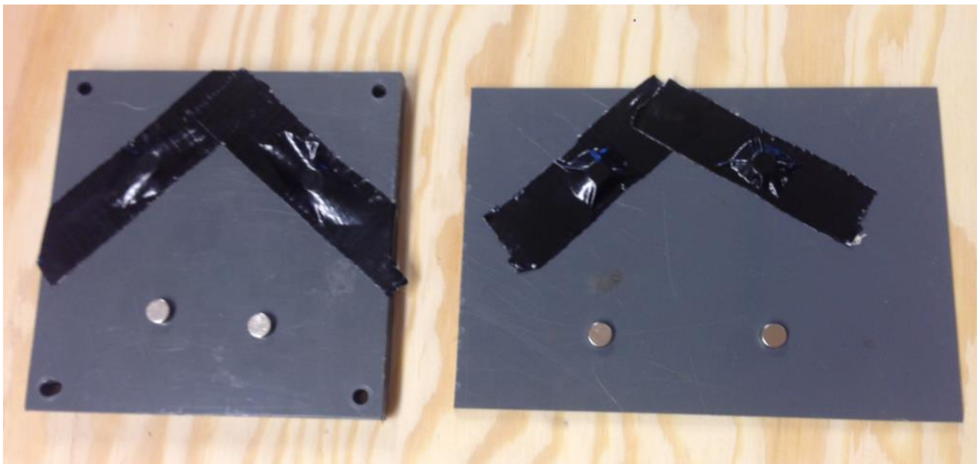

Figure 8.2 Magnetic test with different positionings of neodymium magnets on plates.

The new magnet concept allows the wanted snap and lock in place with 90° rotation possibilities for the CP. Instead of placing the magnets flat on the top of the Puck, they are placed inside the shell of the Puck facing outwards perpendicular to the magnets in the old concept. The magnets are placed in the same way on the CP, but in a female connector. The Puck works as the male connector where the CP attracts and fits in place as female connector. This only requires four magnets on each part. Figure 8.3 illustrates this locking mechanism from a top view.

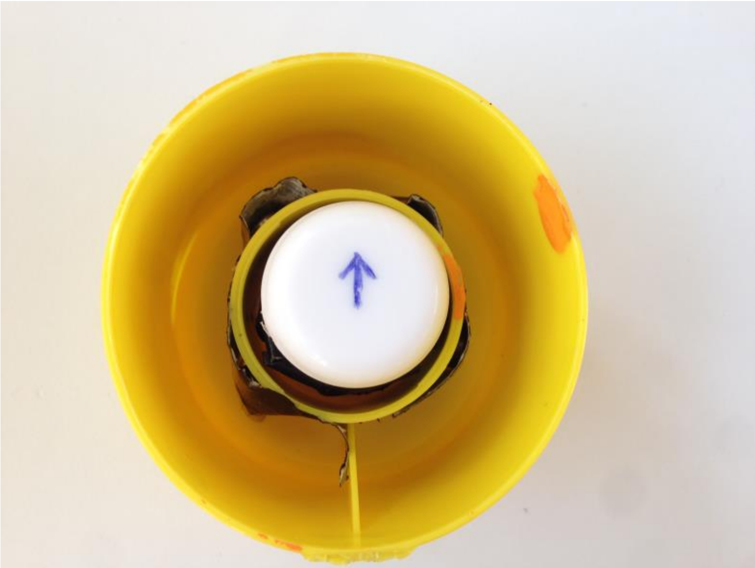

Figure 8.3 Proof of concept for 90° rotational locking.

After the magnetic tests, a very simple prototype was made of the puck and the included components, which makes a very hands-on estimate of the parts' dimensions. All electronic components already have given dimensions, which will make it easier to decide the boundary dimensions of the puck. The tricky part is to puzzle all the components together so they don't take up more space than necessary, yet fulfill the product's criteria. It was made out of cardboard, paper, wires, tape and magnets (see figure 8.4 and 8.5). All the dimensions are found at Electrokit's website on the corresponding product page; Arduino [10], NeoPixel ring [9], wireless transmitter coil and wireless transmitter PCB [7].

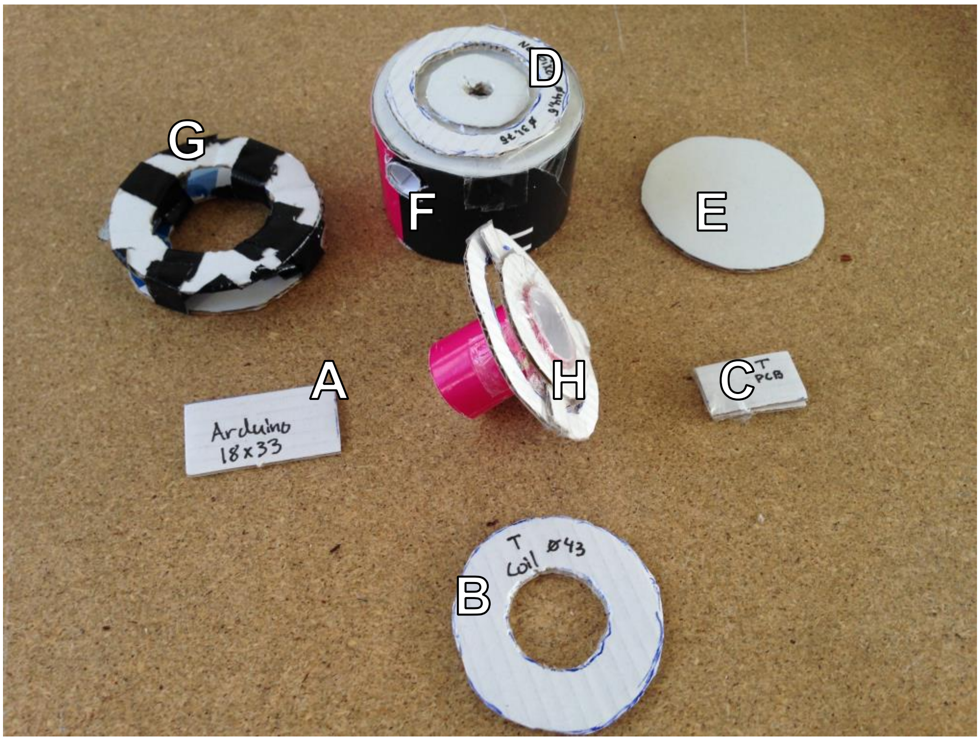

Figure 8.4 Paper mock-up resembles the parts and components of the puck in the concept: A. Arduino pro mini. B. Wireless transmitter coil. C. Wireless transmitter PCB. D. NeoPixel ring. E. Lid. F. Shield and base. G. Magnet ring. H. Feather construction for the Push-button.

The magnet ring is placed just above the power inlet. It has four magnets facing outwards against the shield of the puck. The button spring is connected to the lid, which controls the NeoPixel ring manually. The transmitter coil should be placed as close to the lid as possible and is inserted in the button spring. The receiver coil, which is not displayed here, is supposed to be as close as possible to the transmitter to obtain the best charging possibilities. That is why the transmitter coil is placed as close to the lid as possible, which will also be the analogy for the receiver coil on the CP. The NeoPixel ring is placed underneath the base to provide and spread light on the wall where the puck is placed. All electronic components are placed on the bottom on the base.

Figure 8.5 Full size mock-up prototype of Puck made of paper.

This prototype focuses more on boundary dimensions rather than exact component placement. The cardboard components are for to see if there is, approximately, enough room for them in their designated space. No prototype for the shell for the CP was made, only a paper shell to test the magnet locks was created. The reason for that is that the main focus and problem is the puck. Moreover, it has more components, functions and design requirements than the shell for the CP. The female connection on the CP is designed to fit the puck and it only needs to include one electronic component and four magnets. With that in mind, there is sufficient information to continue to the next step, the CAD process.

8.2 CAD-modeled prototype

The first simple prototype and the newly bought electronic components brought knowledge on how to proceed. Moreover, ideas and guidelines to design detailed parts. Solidworks was used to design all parts to create two assemblies: one for the puck and one for the shell, to the CP. All the included components were designed, even those who aren't going to be 3D-printed. It is easier to visualize the prototype with all components when designing and preparing for the 3D-print. Also, to control if all parts fit and work together. Manufacturing, component assembly, installation setup and actual use are in consideration in the design as well.

To decide what dimensions to use on each part, different tools were used such as a vernier caliper and specification sheets from the retailers of the included components. The designed dimensions of each part that isn't already specified, are customized generally out from four different guidelines:

1. The given dimensions from the included components.
2. Bruder's recommendations for design in plastics, especially regarding injection moulding, found in his book [2].
3. A guide for creating snap fits by the 3D-print experts Wematter [18].
4. General knowledge from the team.

8.2.1 The puck

Lid

The lid (see figure 8.6) is placed on top of the puck and is replaceable. The idea is that the customers have the option to choose a lid, from a limited set of selection, in a customized colour or pattern. The lid is lockable by putting it in the right position in the shell of the puck and then rotating it to the end position. It has a small snap lever that snaps in place in the end position, see figure 8.8. The thickness of the lid gets thinner towards the middle, as seen in figure 8.7. This is to take advantage of the plastic's mechanics and turn it into a button that manually turns on the NeoPixel ring. The lid has four small extruded parts and a lever that locks it and they are designed to fit the shell of the puck with enough gaps to do so.

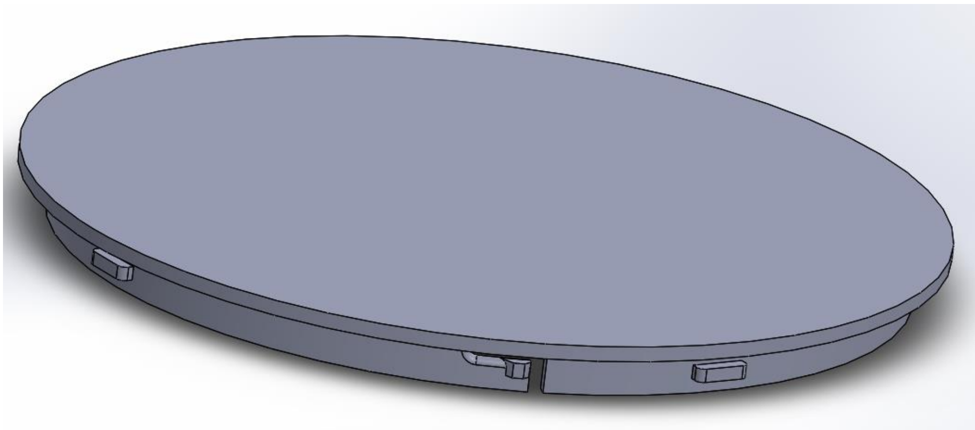

Figure 8.6 CAD model overview of the lid.

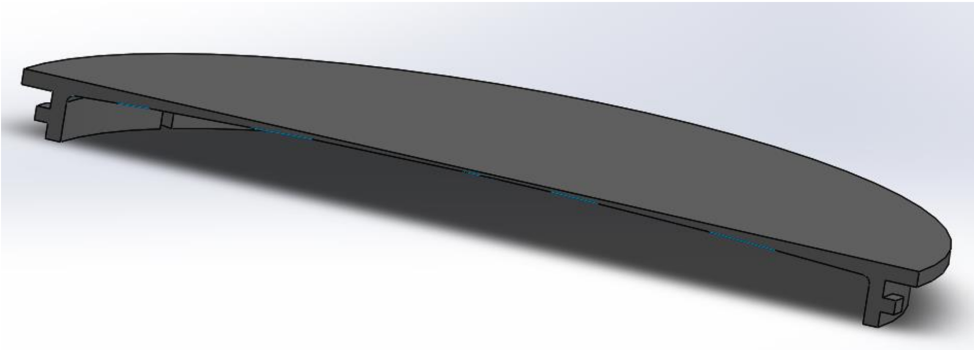

Figure 8.7 CAD section of the lid showing the thinning of the center for easier push.

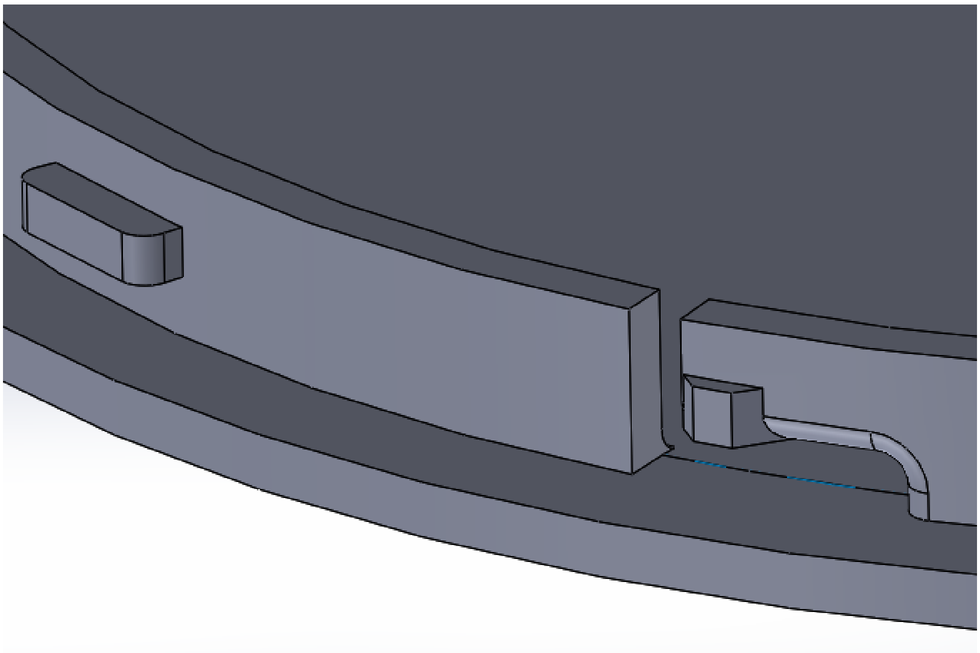

Figure 8.8 Close-up of the locking solution on the lid.

Magnetic ring

The magnet ring (see figure 8.9) is placed inside the puck and should stay in place despite exposed forces. Two snaps, one on each side, locks the magnet ring and are designed to stay in place if the snap-fits don’t bend from the inside. There are room for four magnets in the ring that are designed just enough to fit the magnets. The magnet ring has tracks for the Arduino to fit and a centered hole to allow the button to pass through. Also, there is room for the cables from the transceiver coil, which is placed on top on the ring, to pass through the ring on the outside.

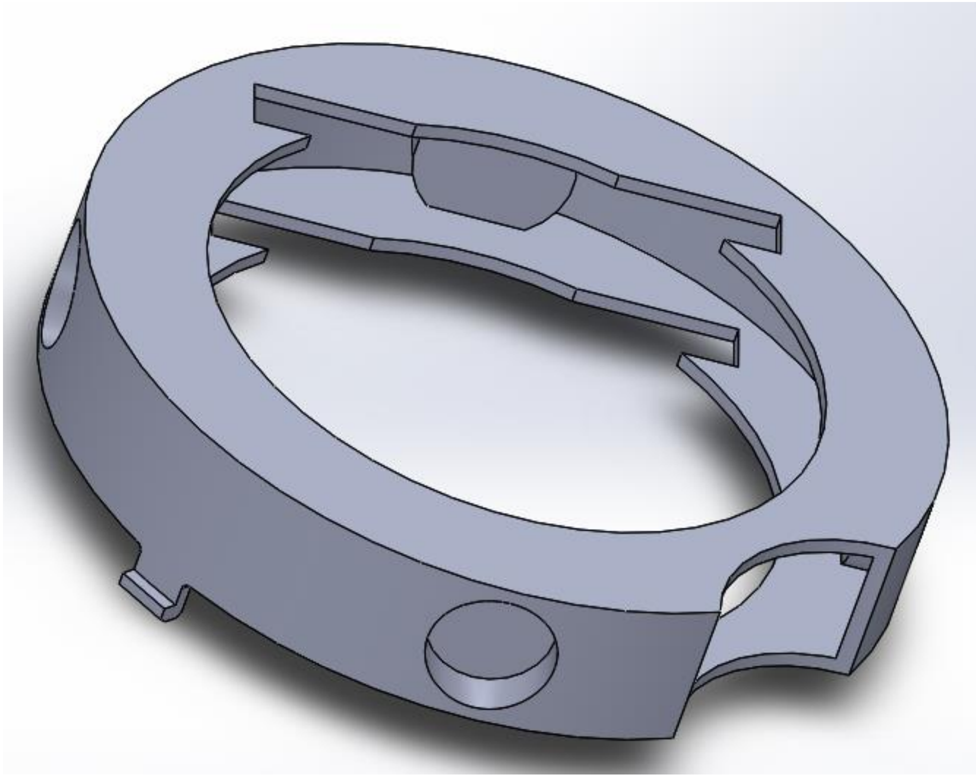

Figure 8.9 CAD model overview of the magnetic ring.

Base

The base of the puck, see figure 8.10 and figure 8.11, has many functions. More specifically, it is the foundation for the Arduino, PCB transceiver, NeoPixel ring, spirit level, DC-jack and button. Also, it is attached to the wall and the shell of the puck is attached to it as well to cover the components. Most of them are glued to stay in place, but the DC-jack stays in place when the base and shell are connected. There are two holes for two screws to keep the base fixed to the wall. There are also holes for the NeoPixel ring wires to be able to connect it to the Arduino. The base has two snap-fits on each side to lock the shell. The release angle is 90°, which means that the snap shouldn't be able to be removed without bending it. The base is mostly loaded by pulling and rotating forces, hence, the snap-fits and two screws.

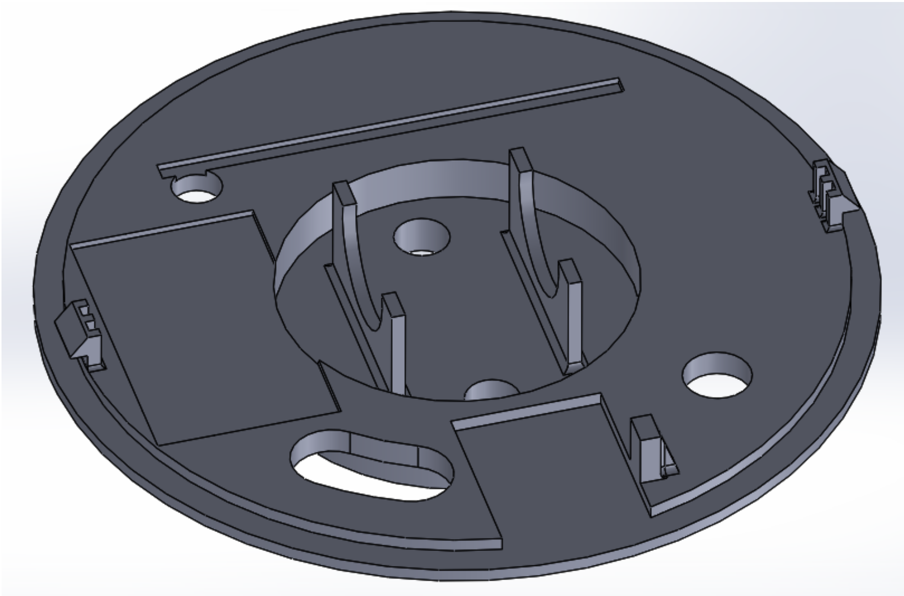

Figure 8.10 CAD model overview of the base (front side).

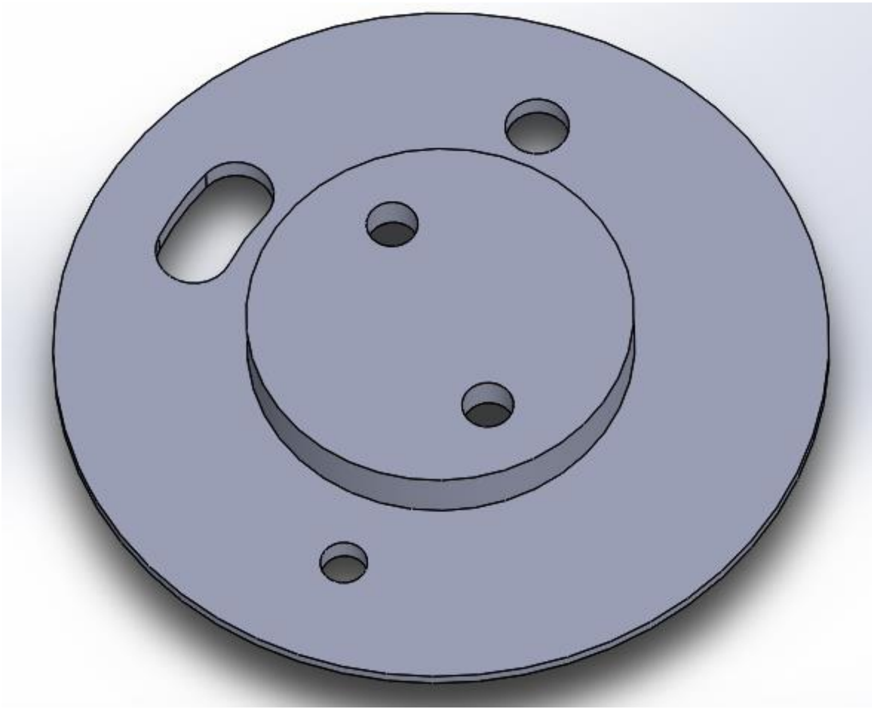

Figure 8.11 CAD model overview of the base (back side).

Shell

The shell (see figure 8.12) is designed to fit the base, magnet ring, lid and be able to hit the button. Therefore, there are a lot of tracks, spots and springs to cover these features. There are space for the magnet ring to slide up and snap into place, space for the snap-fits from the base and user-friendly tracks for the lid to fit and snap in place when rotated. Moreover, four areas that allows the lid to slide down in the right vertical position and when the lid is being rotated, there is one specific place for the lever of the lid to snap in place. The DC-jack is exposed to both pulling and pushing forces when connecting and removing the power cord. Therefore, the small house is provided for it to lock it in place when the shell is attached to the base. The cylinder shaped part is an extension between the lid and button component. It transfers, through three springs, the lid press so that the bottom plate of the cylinder presses the button to switch the NeoPixel ring on or off. The springs are designed thin and curved to create a smooth vertical movement. The thinness takes advantage of the material to create a spring feature without adding any additional parts. The curves create reinforcements and a smooth spring motion.

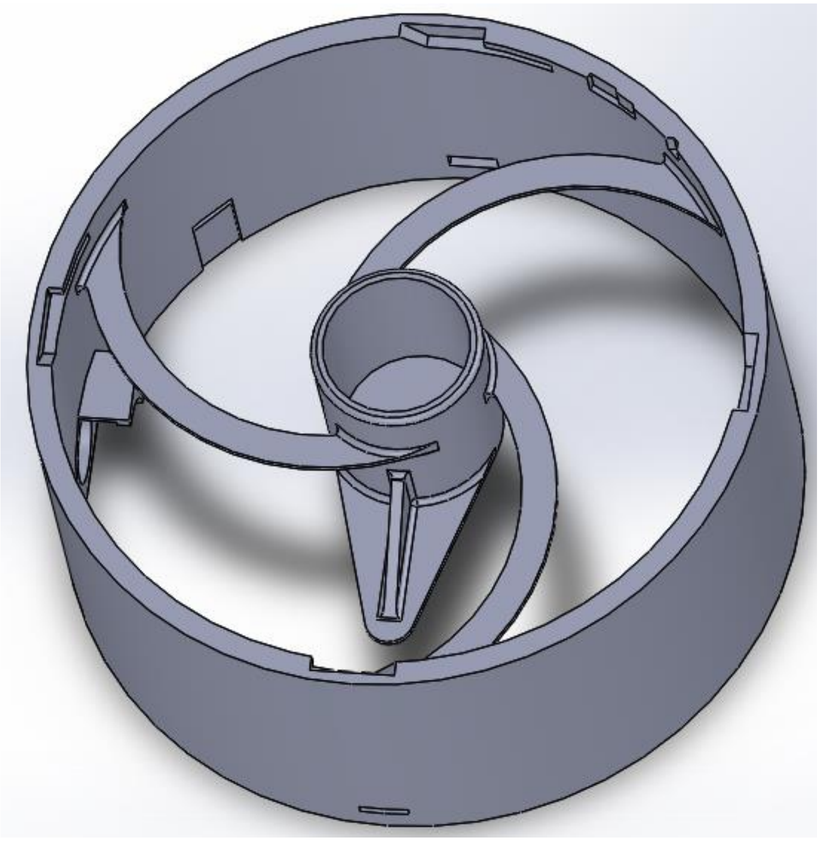

Figure 8.12 CAD model overview of the shell with integrated feather solution.

Snap-fits

All snap-fits (figure 8.13 and figure 8.14) are designed by guidance from the 3D-print experts Wematter [18]. The lead angle, return angle, overhang depth and length of the snap-fit are important parameters. According to the guide, the lead angle should be between 20-30° for the best result. The overhang depth decides how strong the snap-fit is. However, it is important to understand that it requires a longer length, or a design that sustains the second area moment, because a greater overhang depth increases the needed bent to release it. The return angle decides how easily the snap-fit can be removed. A 90° angle is impossible to remove and a 40-50° angle is recommended if it is going to be removed.

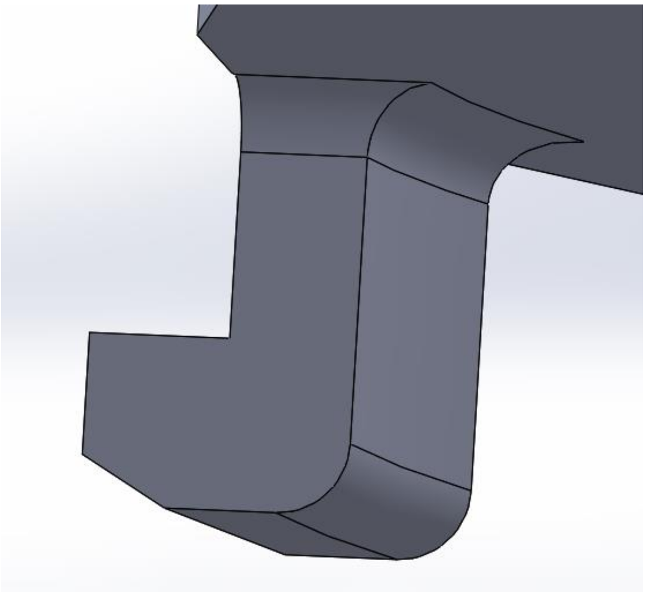

Figure 8.13 Snap-fit on the magnetic ring for locking the ring inside the shell.

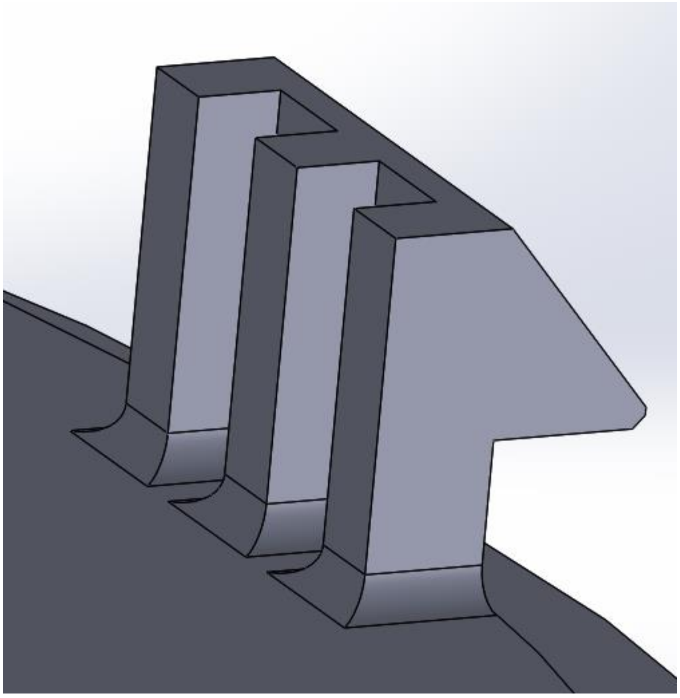

Figure 8.14 Snap-fit on the base for locking the shell with the base.

Locking mechanism

A variety of locking mechanisms are used. Moreover, snap-fits, screws, small tolerances, glue and casing. The screws are only used for the base plate when it gets mounted on the wall. Customers value secure wall attachments for this kind of product according to the identified needs. Screws work for walls in home environments and are simple and reliable. Also, according to the performed benchmark, most wall mounts use screws or at least give that option. Google's Nest for instance, uses two screws and offers easy mounting with snap-fits, see figure 8.15.

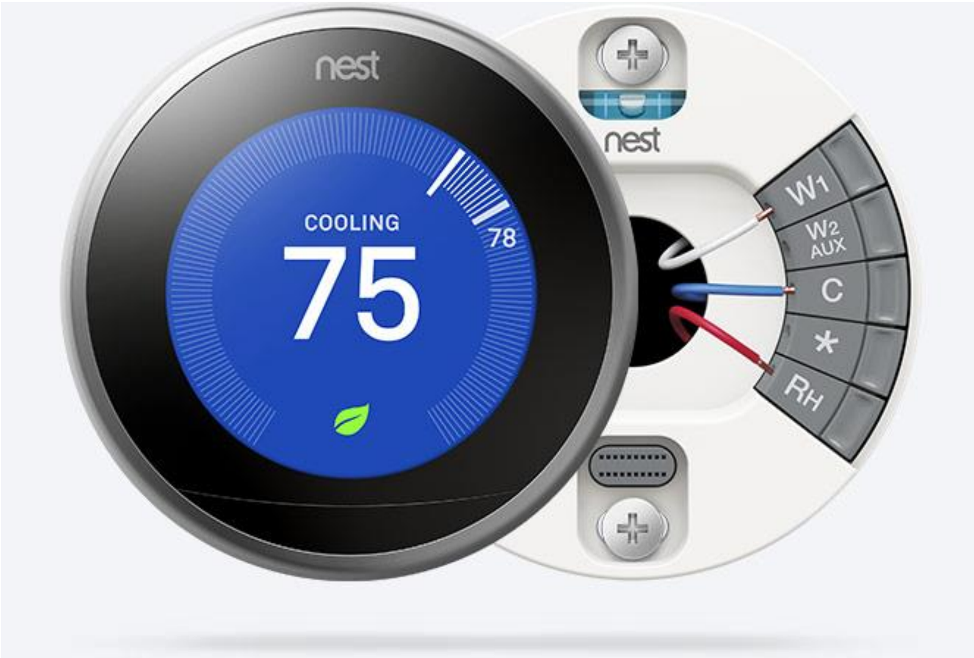

Figure 8.15 Nest product showing the base plate, screws, spirit level, wiring and the touch screen [19].

The setup procedure for the consumers should be easy and quick. For mass production, more parts and assembling steps are usually discouraged because it adds extra time that generates more costs. This analogy is transmittable to consumers but for other reasons - consumers don't want to screw a lot of screws if they can do it easier. Therefore, snap-fits are a great solution for this because they offer a locking mechanism without additional parts. The DC-jack uses a casing function to be locked in place and the magnets use small tolerances, which are both convenient methods. The magnets don't need to be removed so it is only the insertion method in the magnet ring that's important. Conventional circuit boards usually use screws or snap-fits, but in this thesis there are several loose components that are glued in place. It works well for a prototype and the consumers have nothing to do with those components. Otherwise, for a custom-made circuit board for this product, snap-fits or screws would be the best option for mass production due to faster assembling.

Ribs

Bruder's guide to plastic [2] has been essential in this thesis for design in plastics, especially regarding thickness, ribs, reinforcements and injection molding possibilities.

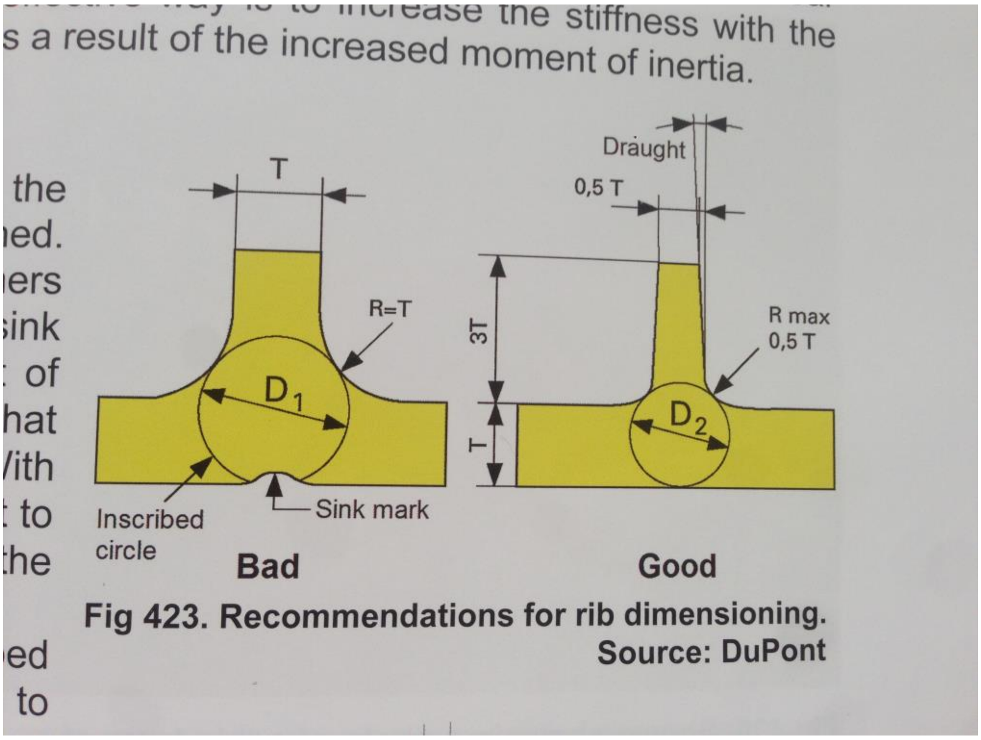

Figure 8.16 Illustrations from Bruder's book explaining how to decide radius and thickness of the ribs in a plastic construction [2, Figure 423.].

Figure 8.16 above, found in Bruder's book [2, Figure 423], explains how the radius and thickness of the rib depends on the initial wall thickness. If the rib is too thick, sink marks can appear during manufacturing. The stress concentration significantly increases if the radius is lower than 0.3 times the wall thickness [2, p. 158], but 0.5 times the wall thickness is a great guideline. According to Bruder, a "normal" wall thickness is between 1.5 - 4 mm [2, p. 157]. The wall thickness for the puck have been chosen to 2 mm and goes down to 1 mm for some smaller areas. This decision is based on the use, the geometry and exposed forces to the puck. It is fairly small with a closed geometry that's fixed to the wall. Therefore, a higher wall thickness is not necessary for use in a home environment. A higher wall thickness adds more demands for manufacturing, which generates more costs.

NeoPixel ring

Some of the components in the product are not intended to be 3D-printed, but are crucial for how to know how to design the puck. The NeoPixel ring (see figure 8.17) is one of them and its dimensions are essential for designing the base plate. It is a very detailed component, same as most of the electronic components that have been bought are. However, the design on those components are not as important except the boundary dimensions and certain functions. Simple models have been made to represent each component except for the NeoPixel ring that was downloaded at the website GrabCAD [20]. The base plate have holes in it at certain locations so that the wires from the NeoPixel can connect to the Arduino. When the NeoPixel is assembled to the puck, it is easy to see where the wires need to go. Therefore, it needs to be placed in a certain location so that the wires don't interfere with other components or features of the base plate.

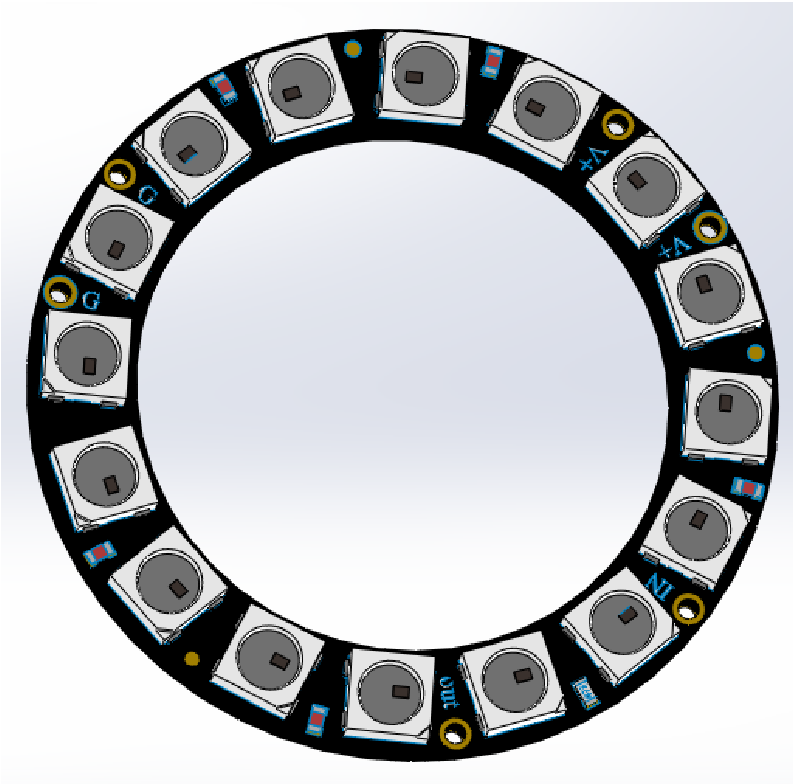

Figure 8.17 CAD model overview of the NeoPixel ring.

Button

The button is placed on the base plate and turns the NeoPixel ring on and off when pressed (see figure 8.18). As mentioned before, the press comes the bottom plate of the cylinder shaped spring that moves by a press from the lid. It is connected to the Arduino that handles how the lights react when the button is pressed. The button is there to allow controlling of the lights manually. Otherwise, the idea for further development is to turn the lights on and change the colour depending on if the CP is not charging, is charging or is fully charged. An option to make the puck glow while not charging is an additional feature to that idea but was easier to implement in the prototype. Also, the button's function is to have a call-and-response with the CP if it gets misplaced. This is not a part of the prototype and will be a part of the further development process.

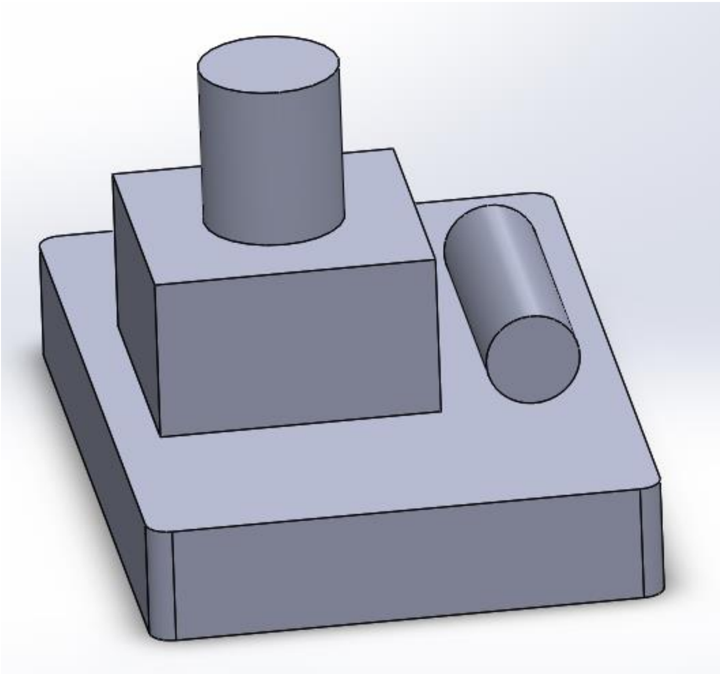

Figure 8.18 CAD model overview of the button solution. The base is a cirquit board and on top is the push-button(left) and a resistor(right). In reality there are some wiring between the two components.

Spirit level

An including spirit level gets more popular by consumer products today. When the consumer mounts the puck on the wall, the spirit level gives feedback to get the proper position. The inspiration came from Google's Nest that is mentioned in the benchmark. For the product in this thesis, it is important to mount the puck correctly on the wall since the magnets lock the CP in 90° intervals. Therefore, a tilted mount would unfortunately not make the CP to get in a horizontal or vertical position. The spirit level (see figure 8.19) is placed on a designated spot in a holder on the base plate. The holder's dimensions are slightly smaller than the spirit level in the first contact area so that it snaps in place when pushed.

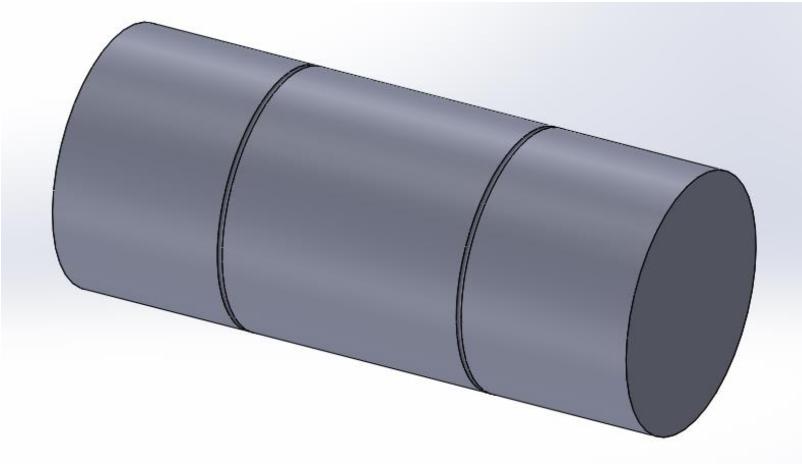

Figure 8.19 CAD model of the spirit level.

DC-jack

A standard 2.1 mm DC-jack is used for easy power input, see figure 8.20. All dimensions for the DC-jack was already provided in a datasheet from Electrokit's website [21]. The dimensions are really helpful to provide a proper case lock for the DC-jack with help from the base plate and the shell of the Puck.

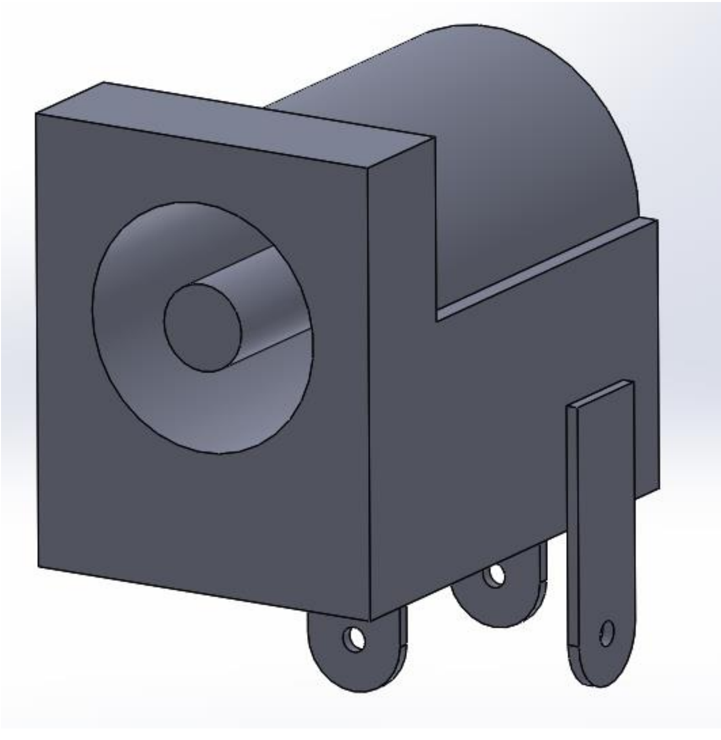

Figure 8.20 CAD model of the DC-jack.

Arduino

A simple model of the Arduino Pro Mini microcontroller was made, see figure 8.21. The depth of the Arduino varies depending on the included micro components. The one with the greatest depth decided the actual depth for the CAD model. It is placed in an upright position in a sink mark on the base plate and through the designated pocket in the magnet ring.

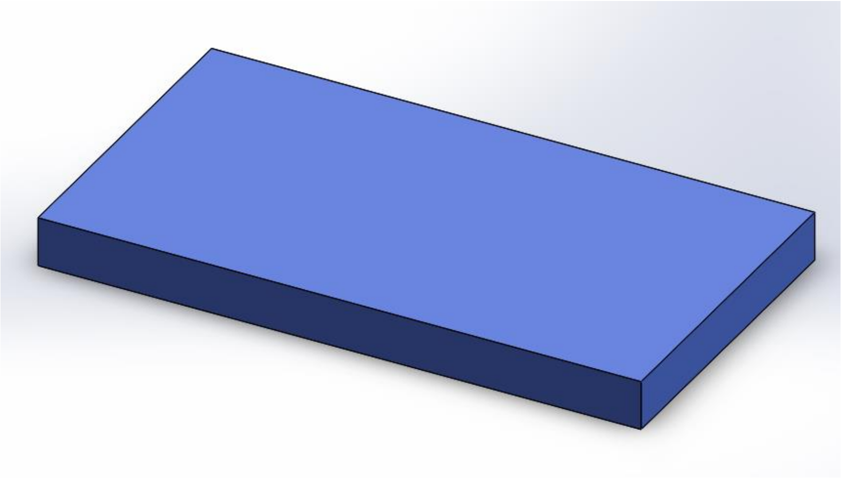

Figure 8.21 Simple CAD model of the Arduino microcontroller.

Wireless charging coil transmitter and PCB

These parts represent the induction charging components, see figure 8.22 and figure 8.23. The PCB is placed at a sink mark on the base plate and the coil is placed on top on the springs on the cylinder close to the lid. The coil needs to be as close to the lid as possible for best charging result.

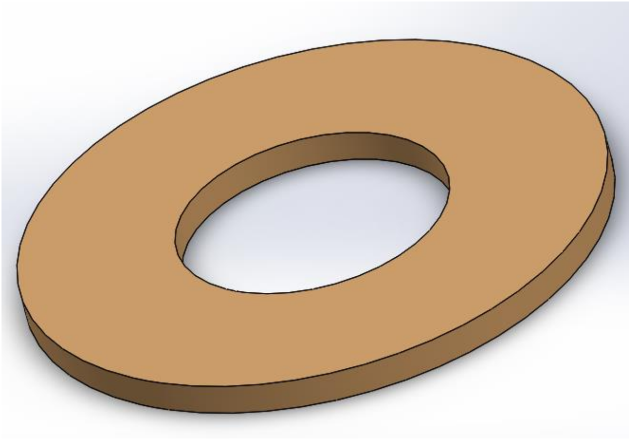

Figure 8.22 CAD model overview of the wireless charging transmitter coil.

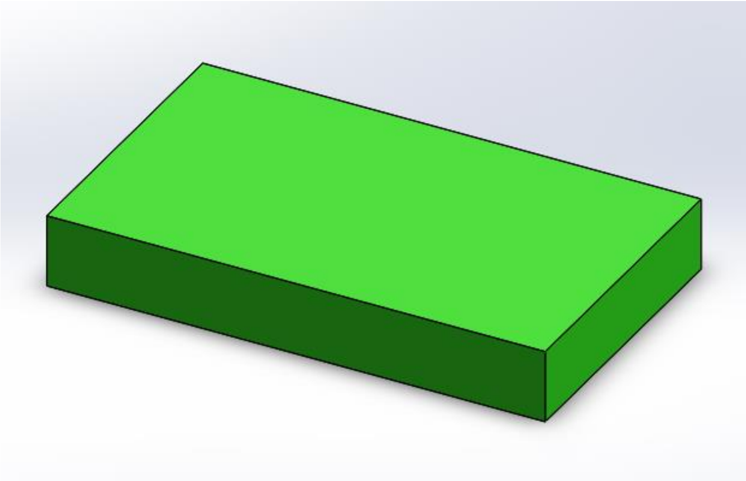

Figure 8.23 CAD model overview of the wireless charging transmitter PCB.

Complete assembly

Once all the parts were modeled, an assembly of everything could be executed to get a better overview of the product. See figure 8.24 for an exploded view of all the components and figure 8.25 and figure 8.26 for more details.

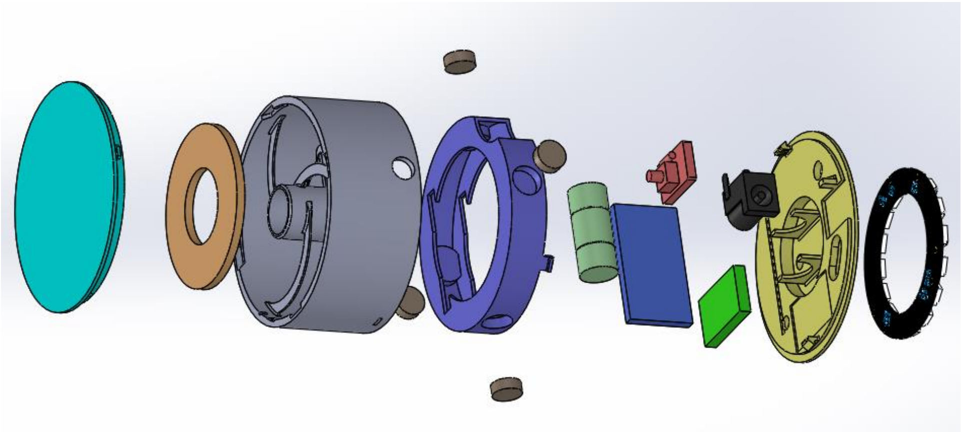

Figure 8.24 Exploded view of the entire puck with all the components.

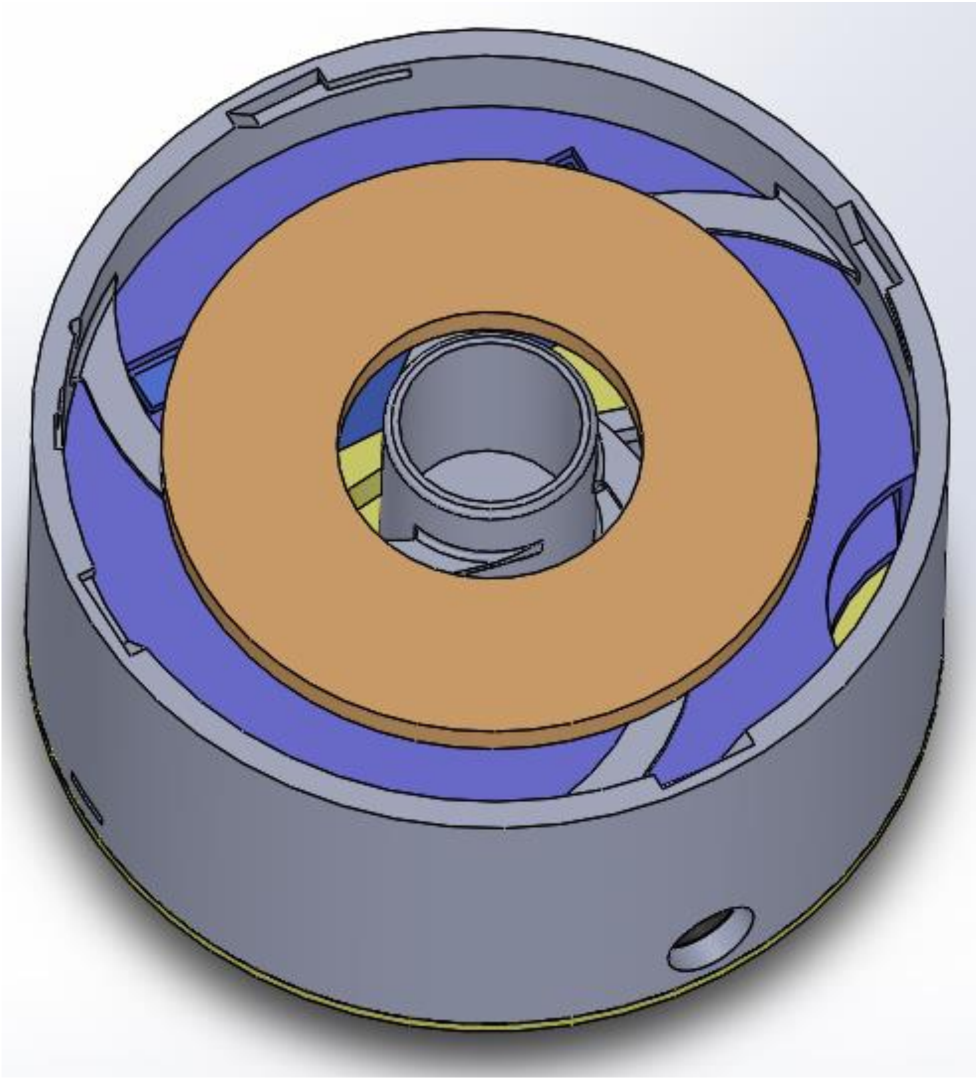

Figure 8.25 Assembly overview of the entire puck without the lid.

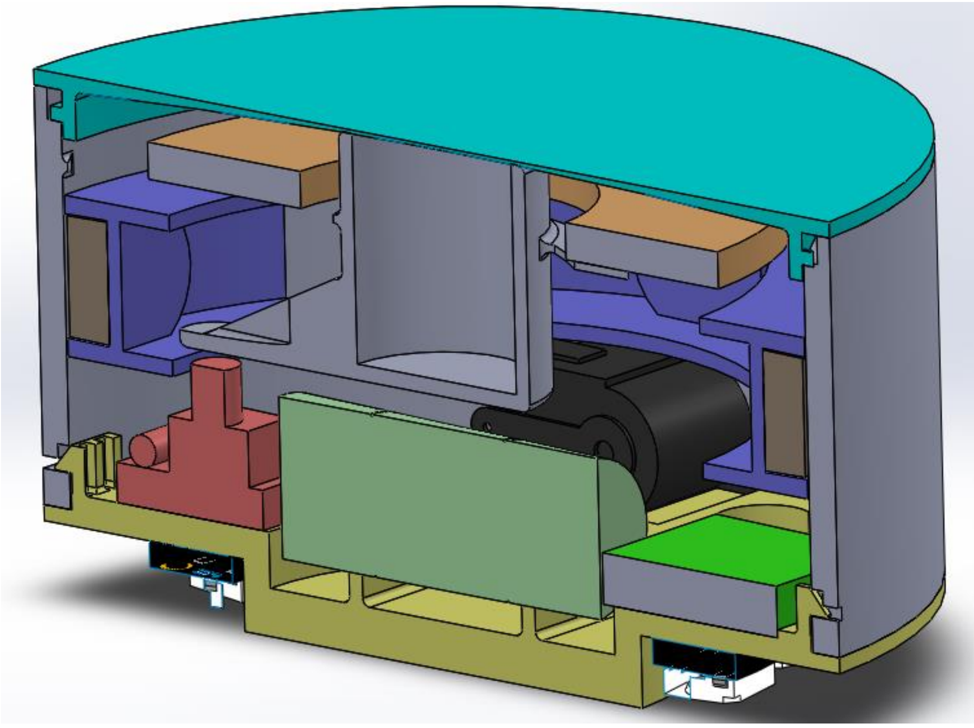

Figure 8.26 Assembly section view of the puck.

8.2.2 Control panel

The casing for the CP (see figure 8.27) is designed to fit a Nexus 7 touch pad. No actual CAD model for the Nexus was made because of all the detailed dimensions and there was no accurate match on GrabCAD either. Instead, the casing got designed by assumptions and approximations from a real Nexus 7, which is the one that is used for the prototype. The Nexus is snapped into place during manufacturing and will be sold as an integrated CP to the customer. On the front side, the casing have sink marks for the PCB and coil receiver where the coil is placed as close to the female area that the puck goes in. The Nexus 7 covers these components when it is put in place and are, therefore, protected. There is also room for the micro USB wire that is connected to the PCB. The micro USB is connected to the Nexus and doesn't show when the Nexus is in place. On the backside, the female ring is located with inserted magnets that snaps to the magnet ring in the puck. It is slightly rounded and with enough gap to easily fit the puck and put it in place. Also, the backside of the casing has a foot that can be flipped out to place the CP on a flat surface (see figure 8.28 and figure 8.29). The foot is a separate part and can easily be assembled by just putting the pins in the right position on the backside.

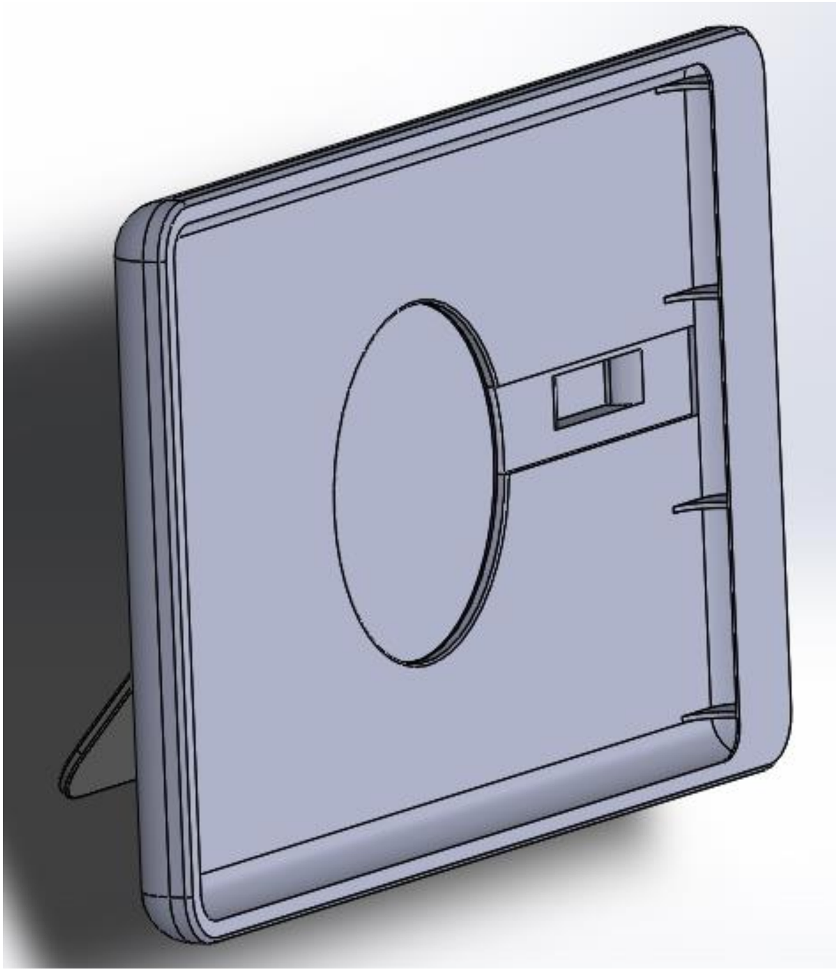

Figure 8.27 CAD model front view of the casing for the touch pad.

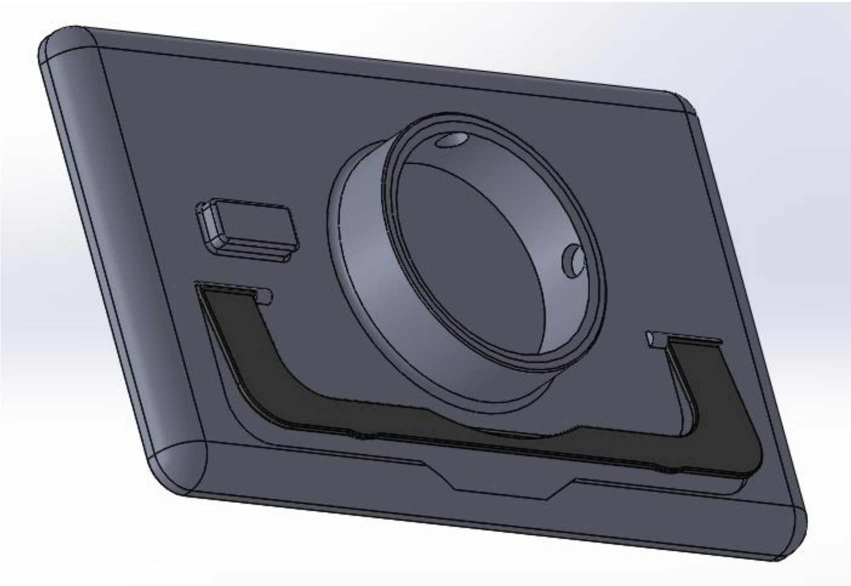

Figure 8.28 CAD model back view of the casing for the touch pad.

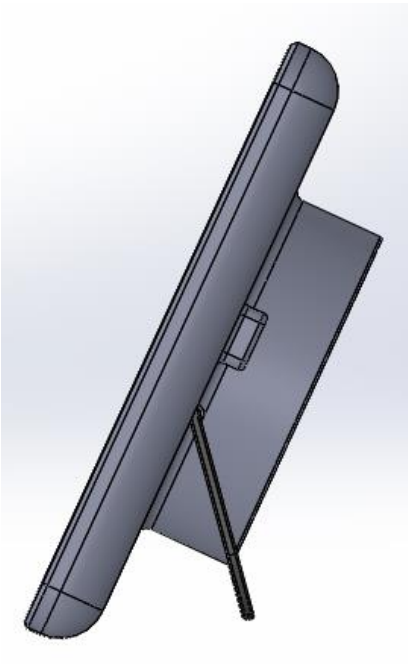

Figure 8.29 CAD model of side view of the casing for the touch pad.

Wireless charging coil receiver and PCB

For the CP assembly both the PCB and the coil got modeled in the same part, see figure 8.30, because the wires' length are critical and decides where the PCB is placed. The coil receives the magnetic field from the transmitter coil from the puck and transmits it to the PCB where the micro USB is connected, which supplies power to the Nexus.

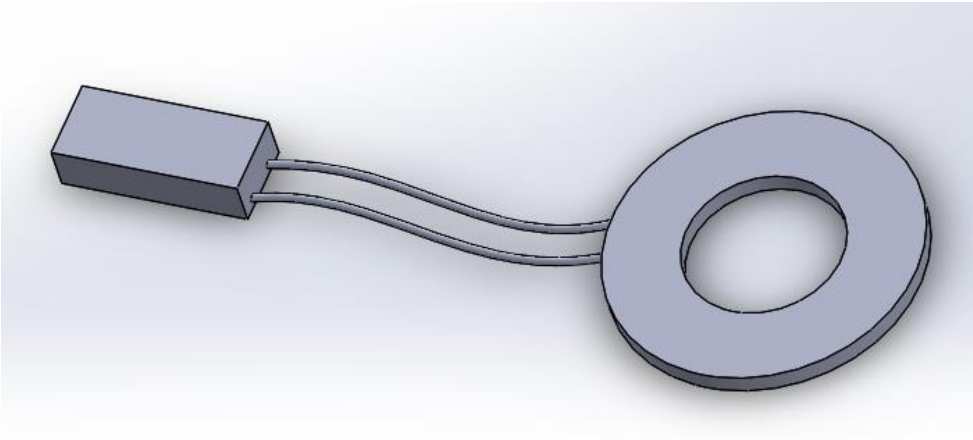

Figure 8.30 CAD model overview of wireless charging coil receiver with PCB.

8.3 3D printing CAD-models

The base plate, the shell of the puck, the magnet ring, the lid, the shell to the Nexus and the stand for it got 3D printed in an SLS machine (see figure 8.31). It is the best printer that Lund University could provide the team with. It prints with great accuracy in the plastic material polyamide. The technology uses the plastic in powder form which is then sintered in layers. Unfortunately, this cause powder remains on the printed parts. The parts are designed for specific dimensions and have very detailed design on several spots. Therefore, the parts need to be cleaned by blowing air and scraping with tools. The material is a bit porous because the material is built through a mesh of triangles which means that it is not completely solid. This makes the cleaning a bit time consuming and difficult.

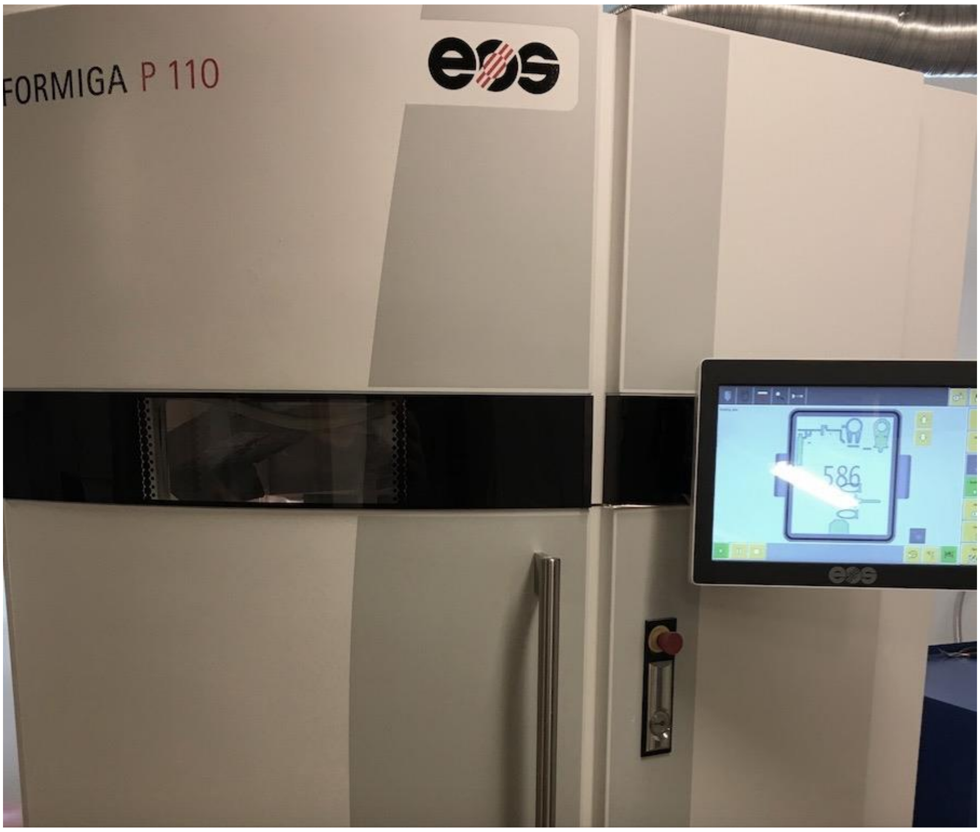

Figure 8.31 SLS 3D printer from Lund University used for printing part.

The 3D-printed parts have rough surfaces which leads to some surface refinements to get the wanted surface quality on some parts, or at least better ones. The most important surfaces that needed refinements were the outside shell of the puck and the inside shell of the female connection on the CP's shell. They need to connect smoothly and effortlessly to give the proper intended user experience. The surfaces refinements were easily made with fine sandpaper.

8.4 Assembly of electronics

The first step in the assembly line was to connect all the electronics. They were assembled directly on the base of the puck as seen in figure 8.32 and figure 8.33. Starting with the NeoPixel ring on the back of the base and then moving on with all the other components on the front. The components were positioned approximately to their finished positions with a margin for the wires to be moved around if needed. All electronics were connected through soldering were some of them were soldered before due to concept testing. Soldered connections needed to be unsoldered again to be able to be assembled correctly and then soldered properly. The electronics in the Puck were soldered together according the schematic presented in figure 8.34 and the electronics in the shell for the CP were soldered together according to the schematic presented in figure 8.35.

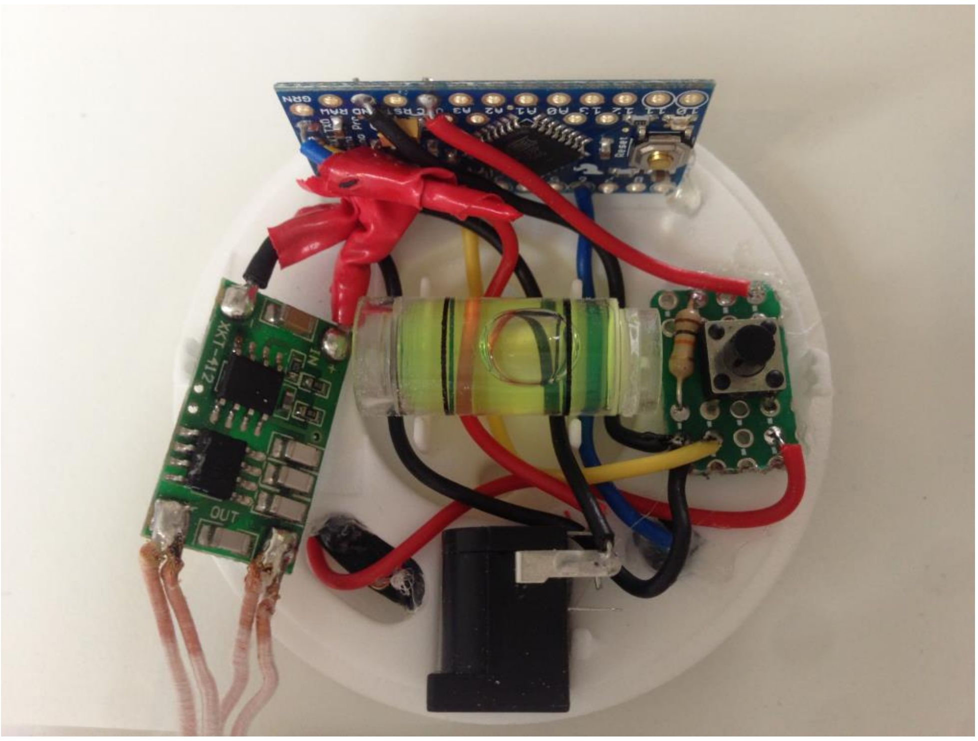

Figure 8.32 Electronics assembled onto the base. Arduino(top), Transmitter coil PCB (left), DC-jack(bottom), button(right), spirit level(middle) and NeoPixel(back)

Figure 8.33 Open puck showing all the electronics assembeled.

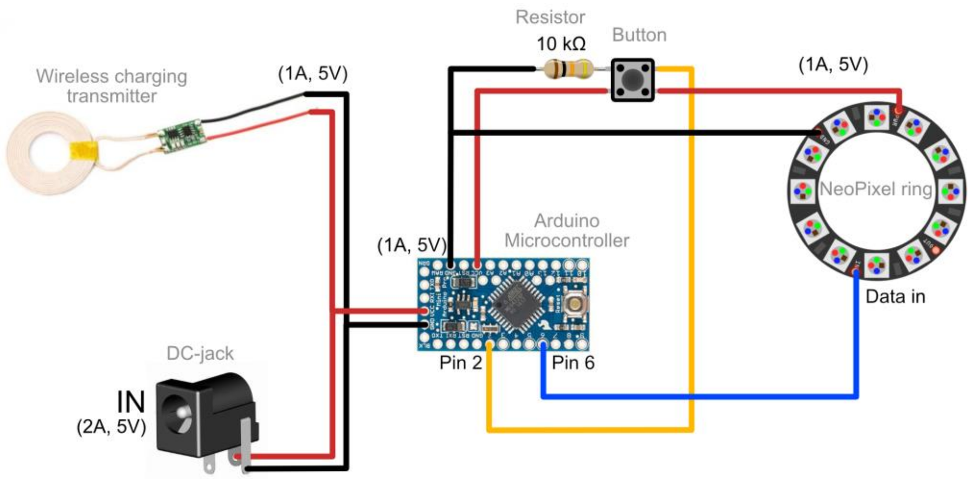

Figure 8.34 Circuit schematic for the electronics of the puck.

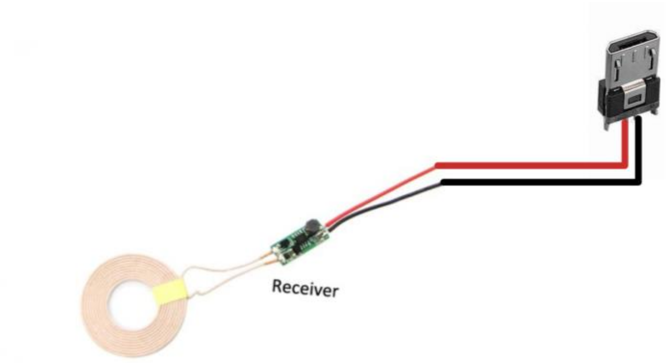

Figure 8.35 Circuit schematic for the electronics of the CP

8.5 Validation test

Before continuing with closing the prototype completely it was required to make sure every part was printed correctly and fitted in their positions. Moreover, every connection and soldering was checked if done correctly, see figure 8.36 and figure 8.37.

The DC power supply that was bought from Kjell & Company [13] was used to power the DC-jack and its connected components. The electronics were tested to determine if electricity went through as it should to all the components, including the wireless charging. After that, all functionalities were tested to see if they worked properly. Almost everything passed the verification tests with two issues identified. Firstly, the DC-jack didn't give out any power to the components. It showed to be a simple misconnection of the pins on the DC-jack and easy fix with a new soldering of the wires. Secondly, the push-function to turn the backlight on/off had some kind of glitch, not keeping the lights turned on when pushed. It worked most of the time and it was still possible to prove the concept, therefore it was not considered as a critical problem.

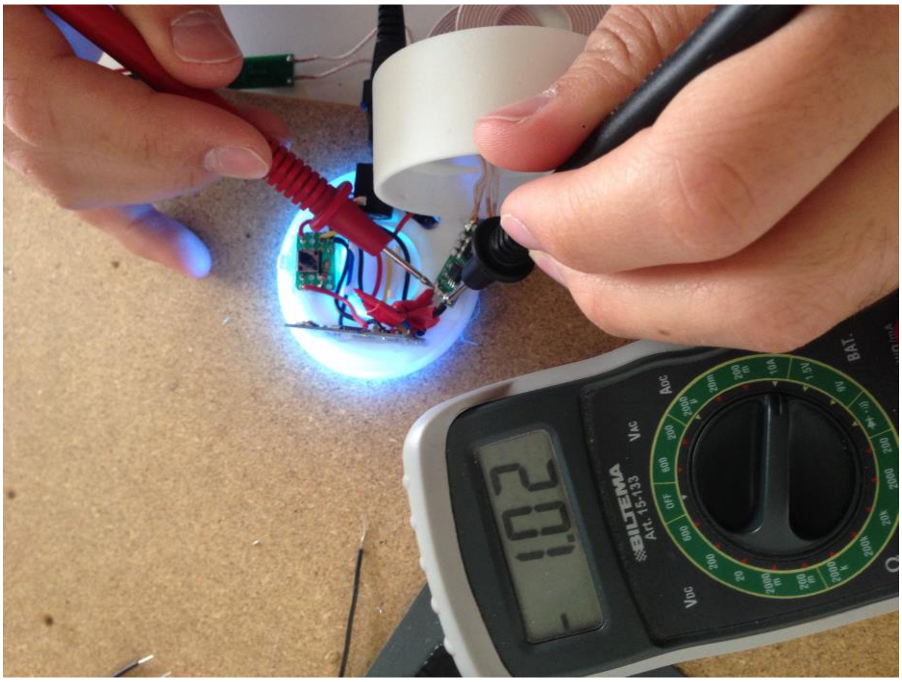

Figure 8.36 Testing electric current output from the DC-jack into the wireless charging coil transmitter.

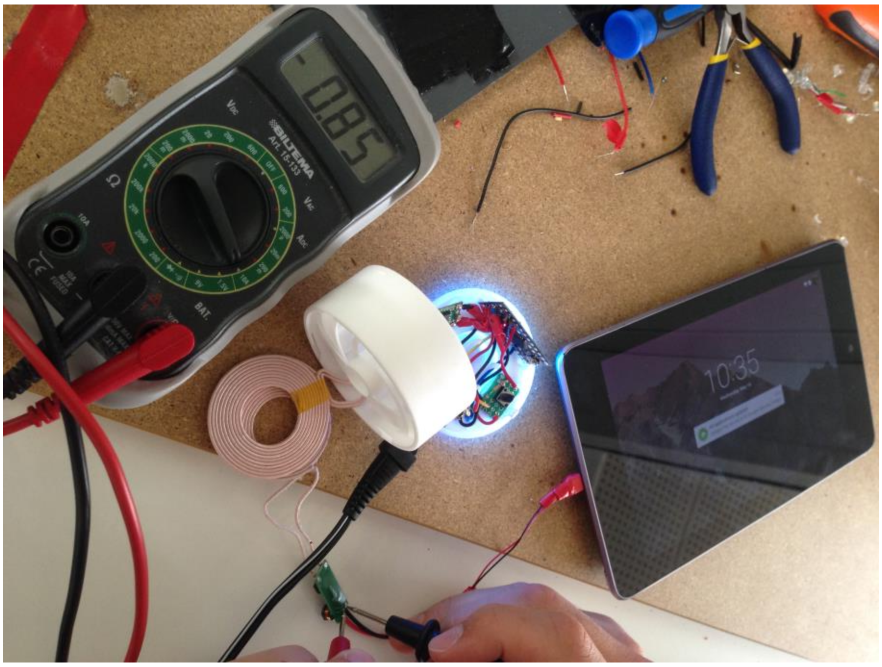

Figure 8.37 Testing if electric current is going in to the touch pad with the wireless charging solution.

8.6 Final assembly

Once all the components were tested and refined to its final stage, they had to be assembled into one single part. The biggest challenge here was to fit all the components in the tight space. Everything was already dimensioned to fit so only some minor changes in the positioning needed to be made. Loose components were then hot glued in their positions to avoid any scramble inside.

Assembling the CP also worked fine. The Nexus touchpad fitted the casing as it was supposed to (see figure 8.39) and the wiring went smoothly in its tracks underneath, as seen in figure 8.38. The PCB of the receiver coil fared just in its housing but more space for it was preferred.

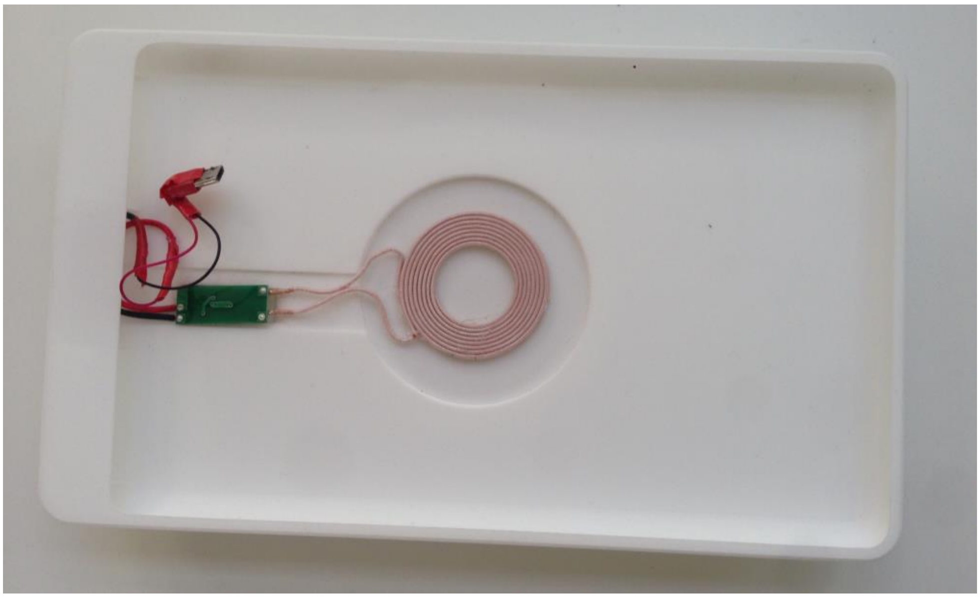

Figure 8.38 The casing of the touch pad, with receiever coil and components included.

Figure 8.39 Fitting the Nexus 7 touch pad into the casing.

When the magnetic locking was tried out the first time one issue was realized. The 3D-printed parts had rough surfaces, which lead to some surface refinements to get the wanted surface quality on some parts, or at least better ones. The gap between the outside diameter of the puck and the inner diameter of the CP ring proved to be insufficient (see figure 8.40). There was too much friction between the two parts and didn't give the smooth feeling that was intended. To solve this, some refinements were made on the surfaces by grinding them down a bit with fine sandpaper.

Figure 8.40 Outside of the puck (Lower) and inside of the ring (Upper) after surfaces has been sandpapered.

Another small issue discovered when assembling all the parts together into a closed prototype, was the snap-fits on the shell. Since there only were two of them, the snap-function was not as strong as wanted. Also, the 3D-printed parts weren't as detailed as expected which made them less accurate. This was solved with super glue between the two parts, see figure 8.41.

Figure 8.41 Glue together the shell with the base because the designed snap-fits weren't strong enough to hold it together.

The magnet ring's dimensions didn't allow it to be assembled as intended. It needed to be cut in some places to allow the wires from the transmitter coil to avoid collision with the DC-jack. Also, the DC-jack had to go through the space that was meant for the coil wires. It resulted in a difficult assemble that needed to be adjusted according to the electronics so that the designated tracks on the puck's inside didn't fulfill their purpose. Because of the alternative assemble, the snap-fits weared more than necessary and needed glue to be held in place.

9 Prototype testing

This chapter explains the testing of the final version of the prototype in aspects as charging capacity, heat radiation, user experience and safety aspects.

9.1 Mounting and placement

The base plate got mounted on a wooden box for demonstrational purposes, see figure 9.1. It worked out well aside from difficulties because of the wires and components on the base plate. This resulted in that the mounting had to be done with care. The two screws that were used to mount it made it rock solid on the box and the help from the spirit level made it much easier to place it correctly. The rest of the Puck was then placed on the base plate and snapped into place, closing everything. The final assembly was made with glue to make it robust enough to use it, as mentioned before. Otherwise, the feeling of the assembly was good except that it didn’t was robust enough without the glue.

Figure 9.1 The PUCK mounted on a wooden box for demonstration.

When the CP is mounted on the puck, it snaps in place and stays there, which feels intuitive and gives great feedback to the user. Also, it can be rotated in any direction to snap in place after every 90° angle. The magnetic locks with the help from the male/female connection makes it stay in place in a robust way. If only the magnets were used, the safety aspects would have decreased a lot.

One issue noticed on the 3D-printed casing of the CP was that the foot (see figure 9.2), which allows the CP to stand on flat surfaces, proved to be quite weak. It was still functional and held the CP standing on tables, but it got bent to a larger angle than wanted. Since it didn't affect the function of the product in any critical way it still passed the verification test.

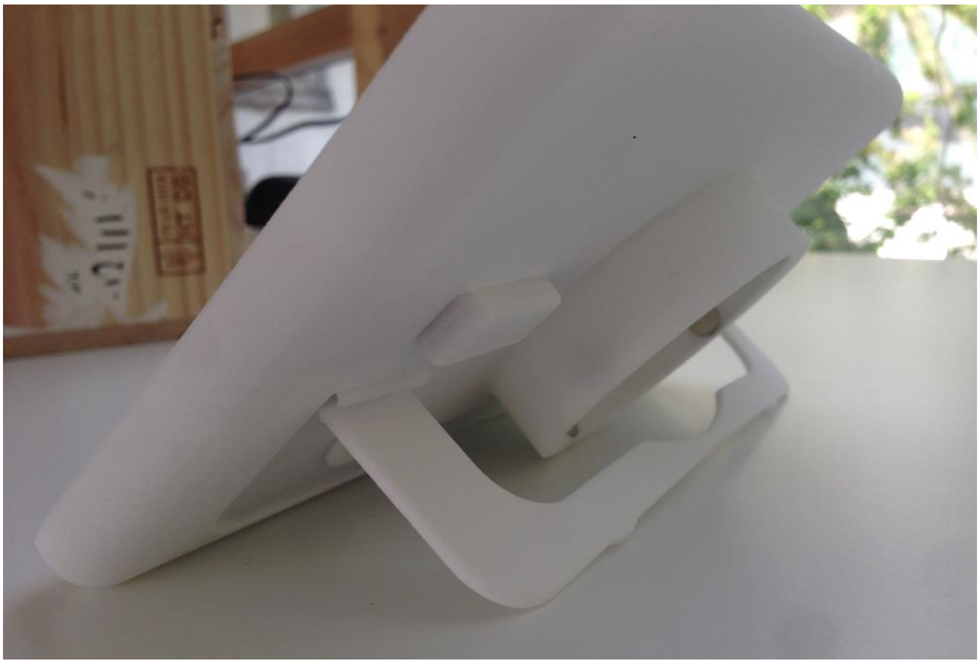

Figure 9.2 CP standing on a table showing the foot support.

9.2 Push button for turning backlight on/off

Everything worked as during the validation test. This time the lid pressed the button to turn the NeoPixel ring on which worked better than expected (see figure 9.3). The feedback from the press was great; moreover, the click sound, the resistance and spring of the press, the tactile feeling and that it turns on the NeoPixel ring in a pleasant way.

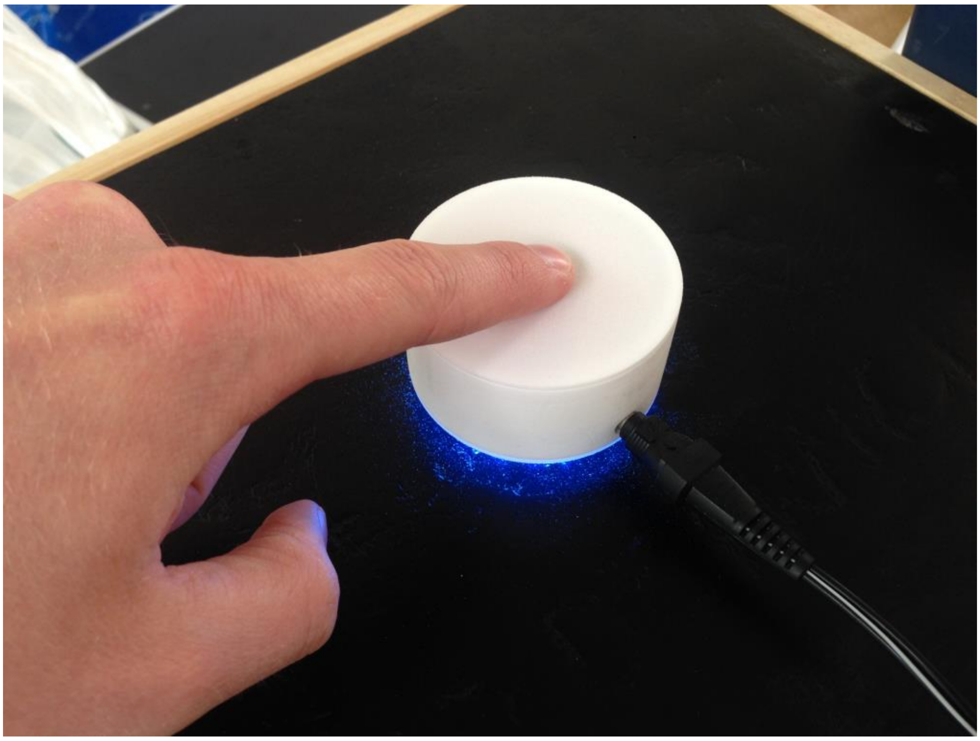

Figure 9.3 The push button being pushed to turn the lights on/off.

9.3 Charging

The Nexus (see figure 9.5) that is used for the prototype is in a bad condition and is not stable enough for such test. Therefore, a conventional powerbank where used for the charging test to measure how fast it can be charged (see figure 9.4). The powerbank has a four-step indicator, which is convenient to use for a simple test. The purpose of the test is simply to see if the induction charger can charge for a longer period at a decent pace. As a reference, the powerbank is also charged through a wired connection for optimal charging. The induction charger can only supply a maximum of 1 A. The powerbank gets 1,5 A from the wired connection which is also the allowed maximum. The expectations are that the wired connection is faster because it is supplied with more current than the wireless connection.

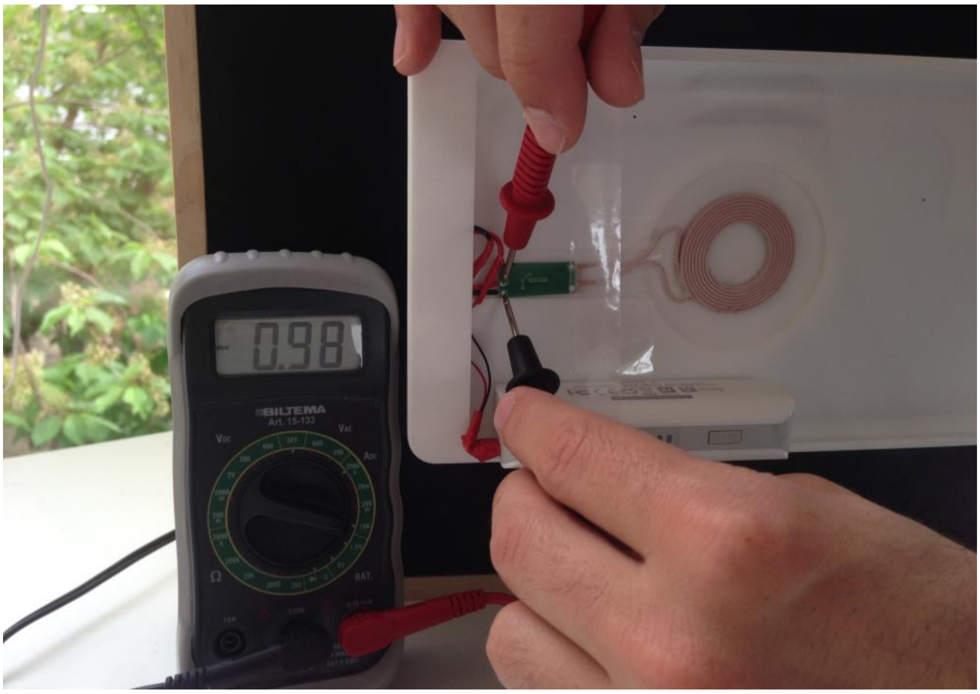

Figure 9.4 Testing the electric current flowing into the battery. Results are showing 980mA.

Figure 9.5 CP docked and charging.

Setup and conditions:

- Start the timer when the discharged powerbank gets charged
- The timer runs in one consecutive charging period
- Stop the timer when the powerbank indicator gets to the third step

Results:

Induction charging - Step three was reached in 2 hours and 40 minutes. The induction receiver receives approximately 1 A.

Wired charging - Step three was reached in 1 hour. The powerbank receives 1,5 A through the wired connection from a computer.

Conclusion:

It is great that the induction charger charges well and receives approximately 1 A during charging. That is the most optimal charging capacity for the component. The distance between the transmitter and receiver coil decides how much current that can be inducted. The wired connection was way faster but had a greater power supply. If the components for the induction charger are changed to components that allow 1,5 or 2 A, it would increase the charging speed a lot. The test shows that the components receive full capacity from the current distance which is good to know for further development.

9.4 Heat

A heat radiation test was made to assure that the puck functions under a longer period of use, see figure 9.6. The puck is closed during use and generates heat due to the electronics such as the NeoPixel ring and charging components. The test shows if there are any critical temperatures in the puck during use. Also, it shows the difference between when the NeoPixel ring is turned on or off.

Figure 9.6 Measuring temperature inside the PUCK.

Setup and conditions:

Initially, all features of the puck is used for maximum effect; the NeoPixel ring is turned on while the CP is charging

- An indoor/outdoor thermometer is used to measure the temperature inside the closed puck.
- The timer starts when the thermometer is in place in the closed puck, the NeoPixel ring is turned on and CP is charging
- The temperature is registered with spot samples during the test
- When the temperature variation is constant or close to constant, the NeoPixel ring is turned off to indicate how much heat the charging generates itself.
- The timer ends when the temperature variation is constant or close to constant when the NeoPixel ring is turned off.

Results of the tests are summarized in table 9.1.

Table 9.1 Heat radiation results with NeoPixel light turned on.

Sample number	***Temperature (°C)***	***Time elapsed (h:min)***
-	26,3	0
1	38,0	0:50
2	40,3	1:00
3	43,2	1:40
4	43,4	2:00
5	43,1	3:20
From here on the NeoPixel light is turned off		
6	37,8	4:20
7	36,9	5:00

Conclusion:

The temperature rises quickly from the start and reaches it peak after 2 hours. The temperature remains slightly above 43°C at maximum effect. When the NeoPixel ring is turned off, the temperature lowers, which is expected, to 36,9°C after 1 hour and 40 minutes. The amount of time is not that relevant, it is the peak temperature with only charging that is more important. Compared to IKEAs induction charger, that was a part of the benchmark, its operating temperature is up to 40°C according to its manual [22]. An article from Bloomberg says that it can operate up to 140°C before the components shut themselves down [23]. In conclusion, the max temperature is close to IKEA:s induction charger and it is not harmful to the puck or the included components.

10 Set final specifications

All the features of the puck are now compared to the specifications that were established earlier in this thesis.

10.1 Final specifications

Some features that are intended in the concept but aren't present in the prototype are taken into consideration during the comparison. However, these will only be the final specifications for the actual prototype and concept. New iterations will come in further development, which will eventually change the specifications. Major changes like a new circuit board can change the specifications a lot. This will mostly concern the dimensions of the puck. Also, the shell to the Nexus is not evaluated in every way, only its features related to the puck.

Table 10.1 Final specifications.

Metric No.	*Need No.*	*Metric*	*Importance*	*Units*	*Marginal Value*	*Ideal Value*	*PUCK*
1	1,2,3,4,5 6,18	Placement	5	List [a]	Wall, Table	All	Wall, Table
2	7,8,17 31	Steps to dock	5	Amount	2	1	1
3	8,19	How easy it is to tip CP from DS	4	Subj.	3	1	2
4	8	Weight of DS	2	g	600	200	300
5	7,9,10	CP insertion angles (alpha/ beta symmetry[b])	4	°deg/ °deg	360/360	180/0	360/0
6	8,13	Locks CP	5	Binary	Pass	Pass	Pass
7	9,17,31	Guides CP to place	4	Binary	Fail	Pass	Pass
8	15,12,16	Removing the CP from the DS	5	s	3	<1	<1
9	11,16	How many tries it takes to remove the CP for the first time	5	Amount	2	1	1
10	13,14,19	How easy it is to accidently remove CP from DS	3	Subj.	3	1	2
11	19,29	How easy it is to move the DS on a flat surface when the CP is docked and in use	4	Subj	3	1	3
12	23,24	Dimensions (width/ height/ depth)	2	mm/mm/ mm	100/100/ 100	< 100/100 /100	60/60/ 32
13	20	Call/response function	4	Binary	Fail	Pass	Pass
14	22,25,27	Material	5	List [c]	Plastic	All	Plastic
15	21,22	Color	5	List [d]	White	All	White

16	30	Angled	2	/°deg	0	0-60	0-40
17	32,33,34	Charging	5	List	Cord	Wireless	Wireless
18	26	Expresses no missing parts	4	Subj.	2	5	5
19	28	Steps to install on wall	2	Amount	4	1	-

[a] List consists of: Any regular interior wall and all solid interior horizontal flat surfaces

[b] Explains symmetry for insertion of parts[5].

[c] List consists of: Plastic, Metal, Wood, Textile, Glass, Silicone and Rubber

[d] List consists of: All possible colors from the CMYK color model

Comments:

The Puck fulfills all marginal values and even a couple of ideal values too. It is good that it meets all marginal values that were established before the concept generation process, which was the initial idea. However, the call/response function is not present in the current prototype but is a part of the concept and, therefore, qualifies as a pass.

10.2 Choice of material

Acetal is the material of choice for the puck and the shell for the CP. That decision is based on the material's properties that suits the products applications. The puck needs to be stiff and tough with excellent friction and wear properties. Also, it shouldn't absorb any type of moisture to avoid dimensional instability and unwanted visual spots. The puck is exposed to constant load at times from the CP and when the CP is removed or put in place, it should be done effortlessly without scratches and traces of wear on the surfaces. All details and properties about the material is found in Bruder's book in the acetal section [2, p. 25].

11 Results

The thesis resulted in a prototype that worked as intended and fulfilled all desired criteria; charging ability, mountable on walls and placeable on flat horizontal surfaces. Also, it was designed to be user-friendly and fit in a home environment. The prototype of the final concept is demonstrated in the figures 11.1 - 11.6.

The prototype includes electronics, components and 3D-printed parts that have been soldered, programmed and connected to work together. It is divided into two parts: One unit, the puck shaped DS, that is mounted on the wall and provides induction charging and one unit that is designed as a shell for the CP. The latter allows the CP to receive induction charging, be placed easily on the DS and allow it to stand on a flat horizontal surface. The CP is docked with ease on the DS with a female/male connection combined with magnetic locking. The magnets are placed to allow the CP to turn 90 degrees in any direction for horizontal or vertical positioning. The baseplate of the puck is mounted on the wall with two screws and with the help of a spirit level to ease the positioning. Then, the rest of the puck gets snapped in place on the base plate. The puck has an inbuilt button that can turn on or off blue backlight with a press on the lid. When the CP is removed from its DS, it can stand on its own with the integrated foldable stand in an angled position. Conclusively, the company Animus Home is satisfied with the results and looks forward to further development and follow-up [24].

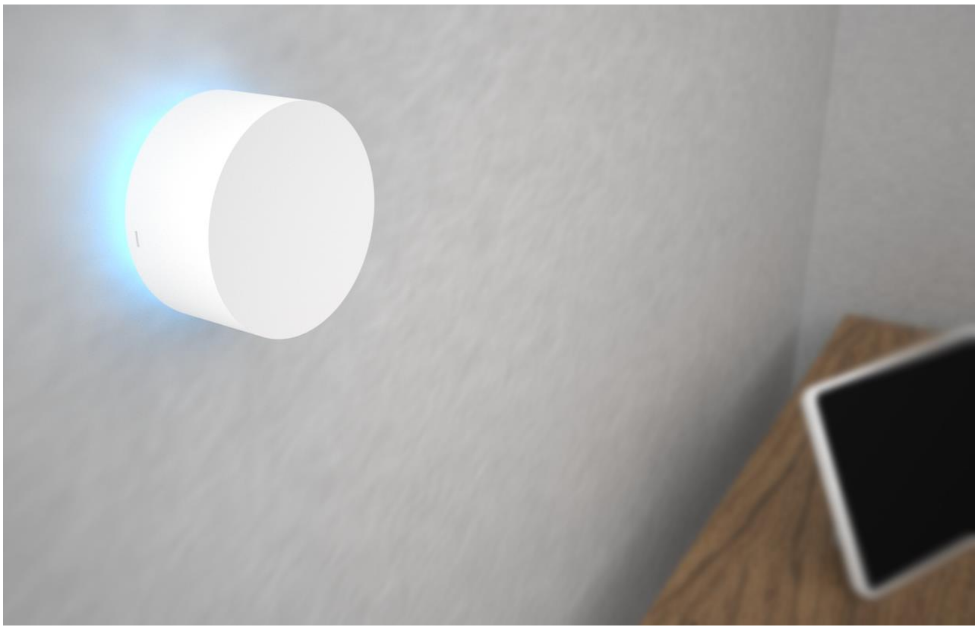

Figure 11.1 Rendered scene of concept PUCK made with Maxwell Studio. CP in the background on a table.

Figure 11.2 The CP docked and charging on the demonstration box.

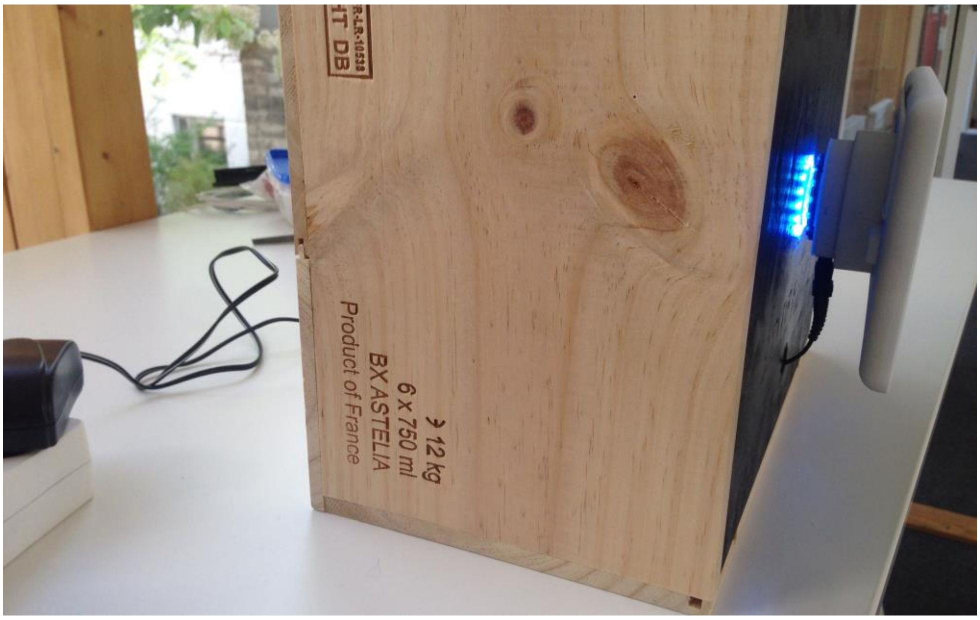

Figure 11.3 Sideview of the complete prototype docked and charging on the demonstration box. Also seen in the image is the power adapter(left).

Figure 11.4 CP docked in vertical alignment on the DS.

Figure 11.5 CP standing on a table with the touch tablet in position.

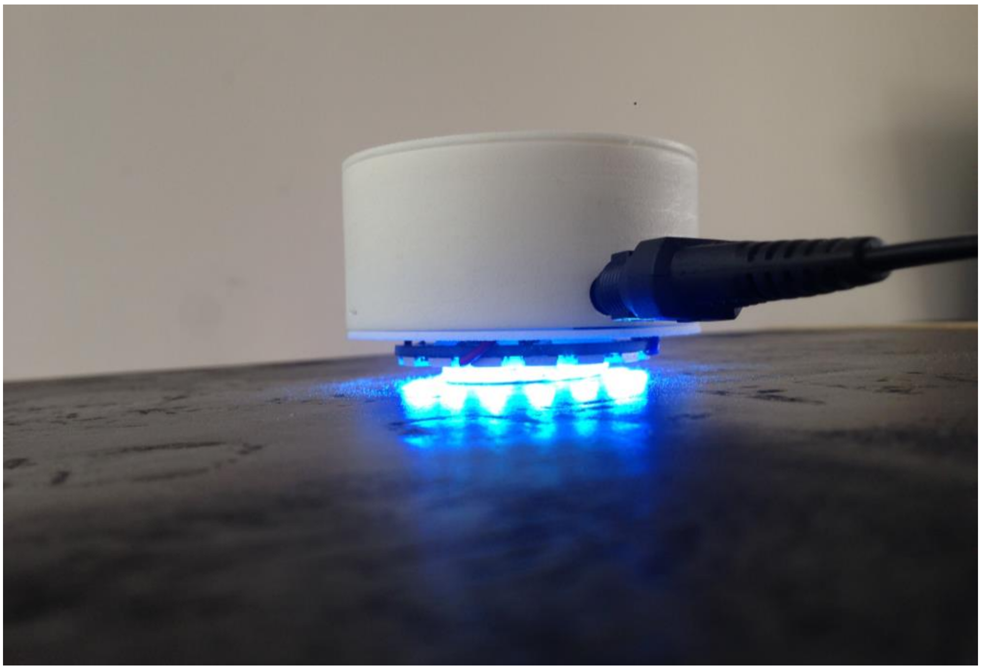

Figure 11.6 View from underneath showing the installed PUCK connected to power supply with backlight turned on.

12 Discussion

Everything regarding the project, results and methodology is discussed in this chapter.

12.1 Reflections about the process

The U&E methodology offers a generic template to follow which is a great tool to structure this thesis. However, at parts, it felt a bit too technical and detailed for this thesis. It usually gives examples for detailed mechanical components for tools or machines. This thesis is more about private customers, consumer goods, usability and home environments rather than tools for companies and craftsmen. The creative process, design aspects and interaction is not emphasized that much during the concept development in U&E's book. There are chapters about industrial design and prototyping, but the links are not that distinct. For further development projects in this area, another book that covers more of the elements in this thesis would be taken into consideration. In this modern era today, there are more focus on design, trends and interactions with the user. The Internet and communication possibilities have changed immensely, which makes U&E's book outdated in certain aspects. However, it gives substantial value and inputs to the project and product development in general. The earlier steps of the project were executed more carefully but after realizing that more focus need to be set on the actual development, the process had to be modified. The optimal way would be to just implement the most interesting and valuable steps for this thesis. Alternatively, use the same or similar content but in another structural way. Although, we are satisfied that we did the pre-studies thoroughly in the first parts of the thesis which gave a solid foundation for the development phases.

12.2 Reflections about the results

The support stand for the Nexus shell was not as good as expected, the design is too weak. Instead of having one pin on each side that connects to the shell, two pins would be much better. Currently, the pins go towards the center of the shell so by adding one pin on the opposite side of each pin, facing outwards from the center, would help as a reinforcement. With one pin on each side, the pressure on the stand is too high which deflects the stand at the connecting point. Basically, the whole Nexus rests on those two pins. Therefore, two pins on each side would even the pressure distribution and minimize the risk of fracture. Also, the prototype's material, polyamide, is stiff and brittle which is not optimal for the intended use.

The design is developed with the user in mind and the prototype is user-friendly in many aspects. However, one thing with the prototype that failed to do so is the mounting process. The base plate is supposed to be free from electronics and wires or at least cover them. The NeoPixel ring forced the base plate to be the main station for electronics because it needs power. Otherwise, an empty base plate with just the spirit level would be the best scenario for the user to mount. With the current prototype, the components take up to much space to add an extra cover for them. But instead of the initial idea of a base plate, it would turn out to be a smaller base puck to mount. The point is to help the user to mount the base plate safe and easy without any risks of damaging the electronics in the mounting process. When the base plate is mounted, the rest of the puck is then snapped in place with all the included electronics. This could be solved by creating a designated circular spot for the NeoPixel ring on the base plate. The base will then have holes around that circular pattern but still be one solid part. The NeoPixel ring, that is a part of the rest of the puck, will rest on these holes and not go through them. This will spread the light on the ceiling through the holes and accomplish the same function as the prototype. Another way to solve it would be to still include the NeoPixel ring on the base plate but add contact pins that contacts to the rest of the electronics in the puck to receive power.

One solution that definitely improves the design and decreases the size of the Nexus shell, is to replace the surrounding shell with a replacement for the originally integrated Nexus shell. There are already products to replace the original shell to give the Nexus a personal touch with included induction charging. That shows that it can be possible to include induction charging to the integrated shell. However, the magnets must be included somehow so it can be connected to the puck. Ideally, the components and magnets will be a part of the shell so that they don't take up much space. The prototype that was made is quite big with a solution that definitely can be optimized. The female magnet connection takes up a lot of space and unnecessary weight. To integrate the magnet locks that matches the initial idea would be best and avoid a female/male connection. A simple, surface against surface, magnetic lock would make the CP more aesthetic, light and slim. However, during the magnetic concept tests, the conclusion was that it was difficult to make the magnets lock the intended way with no female/male connection. The solution for that issue will be left for further development and not covered in this thesis.

The prototype tests were important even though they weren't too thorough. It is easy to underestimate simple tests and sometimes it is not necessary to do it more complex. The heat and charging tests, which were the most detailed ones, confirmed great functionality and safety aspects. The other tests showed that the prototype, and therefore product, has great potential and lives up to the expectations. However, it would be convenient to do better charging tests with the Nexus and compare it with other competitive induction chargers. Unfortunately, most induction chargers only charge within their own brand and accessories which makes such tests difficult to perform. To charge the same tablet with two or more induction chargers would be ideal. As for now, this is only the prototype phase and more redesign iterations will come, which makes the current tests sufficient enough with their results and feedback. For further development, more thoroughly performed tests will be necessary for the final design. Then, better strength and safety tests could be performed with the actual intended material.

12.3 Further development

Something that the prototype doesn’t really fulfill is the construction criterion for production and manufacturing. Some parts of the assembly are completely fulfilled for injection moulding, which is a reasonable manufacturing method for this kind of product. However, the manufacturing aspects for injection molding have been taking into consideration in a large extent during the designing process such as ribs, snap-fits, reinforcements and wall thickness. The next step will be to make all parts ready for mass production. The design process is iterative and there will be more iterations of the design before it is ready for production.

It is difficult to get everything right in the beginning, especially if the product is dependent on a couple of parts that work together. The concept, and all there is to it, can be difficult to implement the intended way. The cylinder spring, for instance, is not compatible for injection moulding. The spring is a part of the whole shell which means that it is very complex and hollow, with different wall thickness that can ruin the molten plastic flow and cause damage to the design. Another drawback is that casted plastic will be difficult to eject from the mould with the current design. However, the concept is interesting and is decided to be tested. Somehow, the button needs to be pressed and the designed solution worked well with the prototype. The feedback from the actual prototype gives information if it is feasible and if it is working or not. If it works, then it can be developed and redesigned into something that is able to be manufactured.

The final design will probably end up in a smaller puck with smaller depth, making an extension between the lid and button unnecessary. All electric components will eventually be replaced with a circuit board. The desire is to make the puck smaller so it doesn’t take up too much space. The current design works but it can definitely be improved and optimized. In comparison with the induction charger from IKEA, mentioned in the benchmark, it has a custom-made circuit board which proves that the design can be optimized and more slim. However, it doesn't include a button or light, but they don't take up too much space anyway. The lid could then probably press the button directly if the button is placed in the middle. The magnet ring would then be removed or replaced with a better suitable solution. The current magnet ring in the prototype could be redesigned anyway. Instead of a ring and extra part, there could be slots for the magnet in the shell of the puck. It would look like circular ribs and still function in the same way - support for the coil, magnetic lock for the CP and more room for wires and components. It would also eliminate the assembly step during the manufacture. Also, as described in the prototype assemble, the magnet ring was difficult to assemble with the current design.

References

[1] Ulrich, K. T. & Eppinger, S. D. (2012). *Product Design and Development* (5th ed.). London, United Kingdom: McGraw-Hill.

[2] Ulf Bruder (2013). *User's guide to plastic*. Karlskrona, Sweden: Bruder Consulting AB.

[3] Hauser, J.R. & Griffin, A. (1993). The voice of the customers. *Marketing Science, 12(1).*

[4] Urban, G. & von Hippel, E. (1988). Lead User Analyses for the Development of New Industrial Products. *Management Science, 34(5).*

[5] Nikoleris, G. (2014). Design for assembly [PowerPoint slides]. Division of Machine Design, Department of Design Sciences LTH, Lund University, Lund, Sweden.

[6] Bytyqi, V., co-founder and software developer, Animus Home, Lund, Sweden. Presentation (2016, March 29).

[7] Wireless charging module 5V 1A. (n.d.). Retrieved June 07, 2016, from http://www.electrokit.com/en/wireless-charging-module-5v-1a.52494

[8] NORDMÄRKE. (n.d.). Retrieved June 07, 2016, from http://www.ikea.com/se/sv/catalog/products/50308304/

[9] NeoPixel ring 16 RGB LEDs ø44.5mm. (n.d.). Retrieved June 07, 2016, from http://www.electrokit.com/neopixel-ring-16-rgb-leds-o44-5mm.51738

[10] Arduino Pro Mini 5V 16 MHz MEGA328. (n.d.). Retrieved June 07, 2016, from http://www.electrokit.com/pro-mini-5v-16-mhz-mega328.46165

[11] [Figure that shows how the Arduino Pro Mini looks like and compares its size with a coin]. (n.d.). Retrieved June 11, 2016, from https://cdn.sparkfun.com//assets/parts/6/5/4/0/11114-04a.jpg

[12] Raja, V. [vigneshraja]. [ca. 2015]. Program Arduino Pro Mini Using Arduino Uno by Raja, V. [vigneshraja] [tutorial]. Retrieved June 07, 2016, from http://www.instructables.com/id/Program-Arduino-Pro-Mini-Using-Arduino-Uno/?ALLSTEPS

[13] Switchad nätadapter 5 V (DC) 10,5 W. (n.d.). Retrieved June 08, 2016, from https://www.kjell.com/se/sortiment/el-verktyg/stromforsorjning/nataggregat/ac-dc/fast-utspanning/switchad-natadapter-5-v-(dc)-10-5-w-p44715

[14] Burgess, P. (2013). Arduino Library Installation by Burgess, P. [library]. Retrieved June 07, 2016, from https://learn.adafruit.com/adafruit-neopixel-uberguide/arduino-library-installation

[15] Arduino. (n.d.). Download the Arduino Software by Arduino [software]. Retrieved June 12, 2016, from https://www.arduino.cc/en/Main/Software

[16] DC-jack 2.1 mm PCB. (n.d.). Retreived June 08, 2016, from http://www.electrokit.com/en/dcjack-2-1-mm-pcb.44282

[17] [Figure that shows how small neodymium magnets look like]. (n.d.). Retrieved June 12, 2016, from http://www.omomagnets.com/img/p/2/6/1/9/2619-home_default.jpg

[18] Petter. (2015). Snäppen i 3D-utskrift av plast by Petter [blog post]. Retrieved June 08, 2016, from https://wematter.se/snappfasten-i-3d-utskrift-av-plast/

[19] [Figure that shows how the Nest Thermostat baseplate mounting looks like]. (n.d.). Retrieved June 12, 2016, from https://pro.nest.com/static-assets/homepage/everyone-talking_2x-83367b4f473f8939fe7dfb5499badea1.jpg

[20] M45t3r 0f H4rdc0r3. (2016, June 28). NeoPixelRing 16x by M45t3r 0f H4rdc0r3 [CAD-files]. Retrieved June 08, 2016, from https://grabcad.com/library/neopixelring-16x-1

[21] Wentronic. (2006, December 14). DC-jack 2.1 mm PCB by Wentronic [datasheet]. Retrieved June 08, 2016, from http://www.electrokit.com/en/productFile/download/3861

[22] IKEA. (2014). NORDMÄRKE Singelplatta för trådlös laddning by IKEA [manual]. Retrieved June 08, 2016, from http://www.ikea.com/gb/en/manuals/nordmarke-single-pad-for-wireless-charging__AA-1419880-3_pub.pdf

[23] Petri, J. (2015, June 26). IKEA'S Charging Wireless Furniture Can't Fix What's Wrong With Your Phone by Petri, J. [article]. Retrieved June 08, 2016, from http://www.bloomberg.com/news/articles/2015-06-26/ikea-s-wireless-charging-furniture-can-t-fix-what-s-wrong-with-your-phone

[24] Bytyqi, V., co-founder and software developer, Animus Home, Lund, Sweden. Presentation (2016, March 29).

Appendix A Work distribution and time plan

Since a group has performed this project, the contribution of each member must be clearly discernible. The work distribution and the project plan outcome are presented in this appendix.

A.1 Work distribution

The work distribution between Martin and Vigan has been even during the whole extent of the project. They were both involved in every activity somehow. It wasn't always the most effective way to work, but the reason for this was to learn as much as possible. It was highly valued in the team for everyone to understand all of the steps in the process.

Although both members were involved in every activity, different responsibilities were assigned. For example coding the microcontroller and assembling the electronics was assigned to Vigan. It was an obvious choice for the team because of his earlier experiences with electronics prototyping. During these periods Martin was automatically assigned other responsibilities such as CAD designs and assembly. Same amount of work was still distributed between the members.

A.2 Project plan and outcome

The outcome of the initial project plan didn't turn out as expected. We decided to focus more on the concept development and leave out system-level design, detail design and testing and refinement for several reasons. Firstly, we wanted to build a great prototype and decided to include electronics, build and connect everything from scratch. That was a major decision that affected the project plan. Secondly, by taking that decision, more work and pre-studies were made to be able to make everything work and to design all parts. It is difficult to estimate the time for this type of development that was decided during this thesis. Finally, this resulted in lack of time to continue with the upcoming steps. Instead, the focus was at making the prototype as close to a real product as possible with the chosen concept selection. You could say that some parts of the upcoming steps were included such as detail design and testing and refinement. They were considered during the prototyping and testing of the product concept. The CAD models were very detailed and well thought-out from the beginning. When they got printed, refinements were made to make it work and behave to intended way or as close as possible. For comparison between the planned project plan and the actual outcome, see figure A.1 and figure A.2.

Task Name	Start	Finish	Duration
Project plan	Mon 16-01-18	Fri 16-01-22	1 wk
Thesis structure	Mon 16-01-25	Tue 16-01-26	2 days
Mission statement	Wed 16-01-27	Wed 16-01-27	1 day
Concept development	**Thu 16-01-28**	**Thu 16-04-14**	**56 days**
Identify customer needs	Thu 16-01-28	Wed 16-02-10	2 wks
Establish target specifications	Thu 16-02-11	Tue 16-02-16	4 days
First draft	Tue 16-02-16	Tue 16-02-16	0 days
Generate product concepts	Wed 16-02-17	Tue 16-03-15	1,8 wks
Select product concepts	Wed 16-03-16	Mon 16-03-21	4 days
Prototyping	Tue 16-03-22	Mon 16-04-04	2 wks
Concept presentation at	Mon 16-04-04	Mon 16-04-04	0 days
Second draft	Mon 16-04-04	Mon 16-04-04	0 days
Test product concept:	Tue 16-04-05	Mon 16-04-11	1 wk
Set final specification:	Tue 16-04-12	Wed 16-04-13	2 days
Plan downstream development	Thu 16-04-14	Thu 16-04-14	1 day
System-level design	Fri 16-04-15	Wed 16-04-20	4 days
Detail design	Thu 16-04-21	Wed 16-04-27	1 wk
Third draft	Wed 16-04-27	Wed 16-04-27	0 days
Testing and refinement	Thu 16-04-28	Wed 16-05-11	2 wks
Thesis	Mon 16-01-25	Wed 16-05-11	78 days
Documenting	Mon 16-01-18	Wed 16-05-04	78 days
Critical review	Thu 16-05-05	Wed 16-05-11	1 wk
Concluding phase	Thu 16-05-12	Wed 16-05-25	2 wks
Project completed	Wed 16-05-25	Wed 16-05-25	0 days

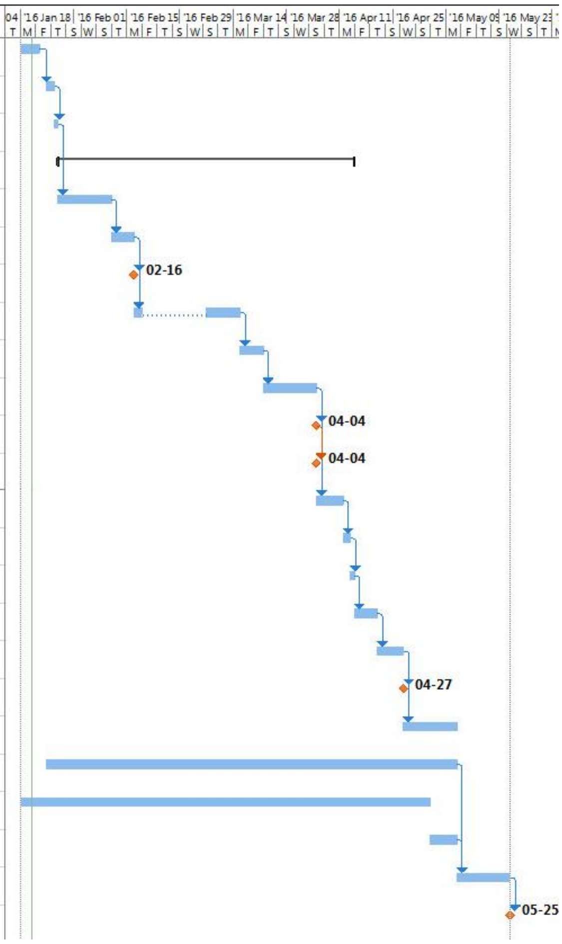

Figure A.1 Planned project plan.

Task Name	Start	Finish	Duration
Project plan	Mon 16-01-18	Fri 16-01-22	1 wk
Thesis structure	Mon 16-01-25	Tue 16-01-26	2 days
Mission statement	Wed 16-01-27	Wed 16-01-27	1 day
Concept development	**Thu 16-01-28**	**Fri 16-05-20**	**81,5 days**
Identify customer needs	Thu 16-01-28	Wed 16-02-17	3 wks
Establish target specifications	Thu 16-02-18	Wed 16-02-24	1 wk
First draft	Wed 16-02-24	Wed 16-02-24	0 days
Generate product concepts	Thu 16-02-25	Tue 16-03-22	1,5 wks
Select product concepts	Tue 16-03-22	Tue 16-03-29	1 wk
Concept presentation at Animus Home	Tue 16-03-29	Tue 16-03-29	0 days
Prototyping	Tue 16-03-29	Tue 16-05-03	5 wks
Second draft	Tue 16-05-03	Tue 16-05-03	0 days
Test product concepts	Tue 16-05-03	Tue 16-05-17	2 wks
Set final specifications	Tue 16-05-17	Thu 16-05-19	2 days
Plan downstream development	Thu 16-05-19	Fri 16-05-20	1 day
System-level design	Fri 16-05-20	Thu 16-05-26	4 days
Detail design	Thu 16-05-26	Thu 16-06-02	1 wk
Third draft	Thu 16-06-02	Thu 16-06-02	0 days
Testing and refinement	Thu 16-06-02	Thu 16-06-16	2 wks
Thesis	Mon 16-01-25	Tue 16-06-14	102 days
Documenting	Fri 16-02-26	Tue 16-06-14	78 days
Critical review	Fri 16-06-10	Thu 16-06-16	1 wk
Concluding phase	Wed 16-06-15	Mon 16-06-20	0,8 wks
Project completed	Mon 16-06-20	Mon 16-06-20	0 days

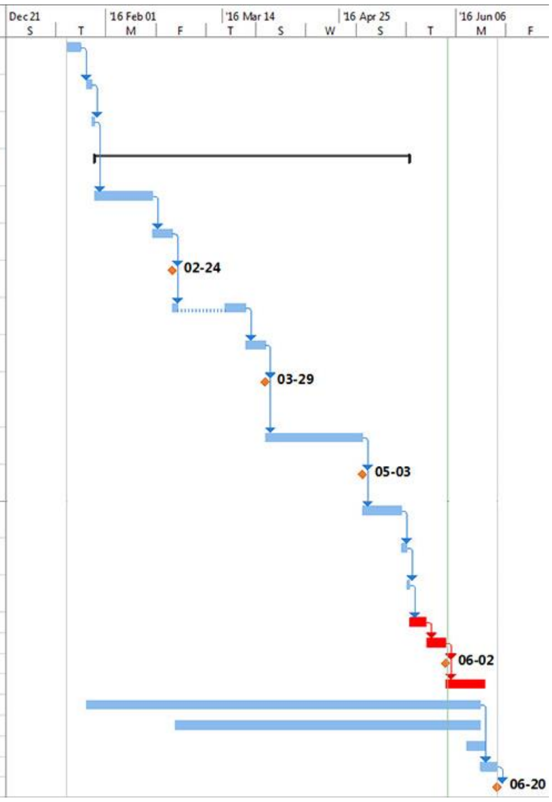

Figure A.2 Actual project plan.

Appendix B Gathered data from interviews

Gathered raw data from interviews are presented in the list below under each question. The interviews were performed in Swedish, which is why they are presented as they were received.

Vad ska dockningsstationen göra för dig?

- Ge laddning
- Avlasta
- Styra mina högtalare
- Låsa panelen på plats
- Styra panelen var som helst
- Ta lite plats
- Stativ så man ser den
- Startklar att kunna användas direkt (upplåst)
- Status feedback
- Smidigt att ställa in
- Ska fungera bra, sitta där och vara estetiskt tillatalande
- Skulle kunna tänka sig att ha flera såndana i hemmet

Var hade du velat placera stationen?

- Vardagsrummet
- Centrala punkten i hemmet (Där man är mest)
- Hallen, centralt och snabb tillgång - nästan alla
- TV-rum
- Kök
- Vid sängen
- Vid dörren (om man har larm)
- Nära ytterdörren - snabb åtkomst till styrningen
- Basstation på vägg - stationär plats
- Beroende på hur stort hus kan jag tänka mig att man vill ha den på fler platser
- Brevid sängen - stänga av allt innan man lägger sig
- Hallen för larm och stänga dörrar

- Sovrummet
- Gömd, behöver inte vara framme
- Definitivt på väggen!
- Inte en sak man går runt med som med ipaden där man testar allt möjligt
- Skrivbordet är för exklusivt utrymme för att ta den platsen
- Vid ytterdörren
- Fästas på kylskåp

Hur hade du velat placera kontrollpanelen på stationen?

- Stående
- På vägg
- Snabbt och smidigt
- Ingen kabel
- Magnetlåsning
- Enkel placering
- Inte på olika håll
- Vinklad ska gå
- Helst ingen docka
- Lätt att ta av och på
- Föreställer sig som en
- Behöver inte ha den i både landscape och portrait
- Lägga på en platta bara, på bord eller platt på vägg
- Ska sitta tryggt där
- Enkelt att placera, möjligtvis magnetiskt
- Helst på vägg, horisontellt eller vertikalt spelar ingen roll
- Vill ha den i portrait p.g.a. tar mindre plats på vägg (spec vid ytterdörren)
- Man ska inte vara rädd att skruvarna åker av när man tar bort den
- Ska vara tydligt på hur man rycker bort den
- Ta av enkelt! inte behöva pilla bakom panelen på något sätt (intuitivt)
- Primärt horisontellt (landscape)

När hade du velat använda dig av docking stationen?

- Vill ha den mest i sin station, men kunna ta av när den ska användas ibland
- När den behöver laddas
- Ha en dedikerad plats när den inte används
- Göra den tillgänglig för andra
- En call-funktion på den när jag glömt var jag lagt kontrollpanelen
- Laga mat
- Läggdags
- Används mest på väggen
- Den lär vara på sin station rätt mycket

- När CP behöver laddas
- När man vill ställa undan CP
- När jag lämnar hemmet och behöver ställa in den i borta-läge
- Vid snabb användning (tar loss den när jag behöver göra ändringar i inställningarna)
- På kvällen för att ladda den
- För att få reda på var den är
- När han vill ändra på något
- För att få snabb överblick när man kommer

Hur viktig är designen för dig och på vilket sätt?

- Designen är mycket viktig
- Sladdlös laddning
- Lutning
- Lyxiga material, dansk design inspirerat
- Neutral och modern
- Slimmad
- Passa bra i hemmamiljö
- Smart
- Diskret
- Snygg linje
- Greppvänlig
- Enhetlig med resten av produkten (produkterna)
- Ta lite plats
- Svart eller vit
- Ok med en sladd som hänger, men endast en
- Passa in i hemmet – diskret
- Någon typ av feedback att den är på/laddas/..
- Vinkel
- Valmöjlighet på design, så den passar in i miljön
- Ska kännas säker när man väl sätter dit den
- Diskret och kunna välja färg på den beroende på vad man har för tapet
- Smutsavisande
- Anti-reflex på skärmen
- Vinklar anpassad för olika höjd
- Stilren, clean yta
- En simpel färg, mindre storlek
- Okej att en sladd syns
- Se bra ut och hålla i längden
- Hög kvalité
- Inga skrikiga färger
- Ta lite plats och bra att kunna vinkla

- Man ska inte kunna se att där saknas någon panel där
- Liten cirkel i metall
- Diskret hängandes sladd

Hur skulle du vilja ladda produkten?

- Klickas i själv
- Magnetkontakt
- Induktionsladdning
- Ingen sladd
- Inte jätteviktigt att det är trådlöst
- Enkelt och gärna sladdslöst
- Bara ställa den
- Indikation på att den laddas
- Som en trådlös telefon
- Inget som sliter på kontakten
- Trådlös laddning

Övrigt:

- Call/response (nästan alla)
- Styra med röst
- Extra kostnad med Call-funktion men kan vara bra att ha

Appendix C Code for the NeoPixel ring

Attached in this appendix is the complete code for the NeoPixel ring.

```
NeoPixel library

#include <Adafruit_NeoPixel.h>
#ifdef __AVR__
#include <avr/power.h>
#endif

// Which pin on the Arduino is connected to the NeoPixels?
#define PIN 6

//Which pin on the Arduino is connected to the Button
#define BUTTON_PIN 2

// How many NeoPixels are attached to the Arduino?
#define NUMPIXELS 16

// When we setup the NeoPixel library, we tell it how many pixels, and which pin
to use to send signals.
// Note that for older NeoPixel strips you might need to change the third
parameter--see the strandtest
// example for more information on possible values.   Adafruit_NeoPixel pixels =
Adafruit_NeoPixel(NUMPIXELS, PIN, NEO_GRB + NEO_KHZ800);

bool oldState = HIGH;
int show = 0;
int delayval = 500; // delay for half a second

void setup() {
    pinMode(BUTTON_PIN, INPUT_PULLUP);
    pixels.begin(); // This initializes the NeoPixel library.
    pixels.show(); // Initialize all pixels to 'off'
}
```

```
void loop() {
    // Get current button state.
    bool newState = digitalRead(BUTTON_PIN);

    // Check if state changed from high to low (button press).
    if (newState == LOW && oldState == HIGH) {
        // Short delay to debounce button.
        delay(20);
        // Check if button is still low after debounce.
        newState = digitalRead(BUTTON_PIN);
        if (newState == LOW && show == 0) {
            show=1;
            colorWipe(pixels.Color(0, 0, 0), 50); // Black/off
        }
        else{
            show=0;
            colorWipe(pixels.Color(26, 136, 195), 50); // Animus Blå
        }
    }

    // Set the last button state to the old state.
    oldState = newState;
}
//*** Här tar den viktiga koden slut ***


//***NEDAN FINNS OLIKA STILAR PÅ LJUSET ATT PLOCKA IFRÅN***

// Fill the dots one after the other with a color
void colorWipe(uint32_t c, uint8_t wait) {
    for(uint16_t i=0; i<pixels.numPixels(); i++) {
        pixels.setPixelColor(i, c);
        pixels.show();
        delay(wait);
    }
}

// Slightly different, this makes the rainbow equally distributed throughout
void rainbowCycle(uint8_t wait) {
    uint16_t i, j;

    for(j=0; j<256*5; j++) { // 5 cycles of all colors on wheel
        for(i=0; i< pixels.numPixels(); i++) {
```

```
            pixels.setPixelColor(i,Wheel(((i*256/pixels.numPixels()) + j) & 255));
        }
        pixels.show();
        delay(wait);
    }
}

//Theatre-style crawling lights with rainbow effect
void theaterChaseRainbow(uint8_t wait) {
    for (int j=0; j < 256; j++) { // cycle all 256 colors in the wheel
        for (int q=0; q < 3; q++) {
            for (int i=0; i < pixels.numPixels(); i=i+3) {
                pixels.setPixelColor(i+q, Wheel( (i+j) % 255)); //turn every third
                pixel on
            }
            pixels.show();
            delay(wait);
            for (int i=0; i < pixels.numPixels(); i=i+3) {
                pixels.setPixelColor(i+q, 0); //turn every third pixel off
            }
        }
    }
}
```

Appendix D Self evaluation

We are very pleased with the results. The prototype works as intended - a DS that allows charging where the CP can be mounted on the wall or placed on a flat surface. It's not only working in a functional way, it's a prototype that is directly user-friendly and appealing for the customer. That is a big difference that we are happy to have accomplished. For instance, the lid that works as a button, is very tactile and works really well for the user. One thing that could have been better with the prototype regarding the intended use, is the stand for the CP. It can only be used with care to avoid any chances of fracture.

The prototype includes electronics, components and 3D-printed parts that have been soldered, programmed and connected to work together. Fortunately, we had skills to be able to do so and, also, we knew what components that worked together and not. That is something that was really valuable in the development process because it's outside our field of area.

The 3D-printed parts fitted well with each other and the other components, which is very positive to get right on the first try. It's a huge time loss for the project if another 3D-print is required, especially if it's about to have a functioning prototype. It's wise to at least count one more print just in case because a design process is usually iterative. There were only minor design errors that could be fixed afterwards and, also, mechanical limitations because of the 3D-printer such as small details and material properties.

No parts from other products have been used, everything is developed just for this thesis. The only exceptions are the parts that have been bought. However, this thesis is about product development that includes a lot of steps and components to function the right way. It's not about developing all components because it's not covered in the thesis, our specialization and the restricted time. Most of the bought components are intended for do-it-yourself applications and works great for prototyping.

We planned to include more parts of the U&E's product development process and we learned that it usually takes longer time than expected. In the beginning of the planning process, there were more focus on the actual steps and parts that we wanted to cover rather than the actual outcome. Of course, it's difficult to know in what direction the project will take. We had in mind that the project plan wasn't final and that the last steps of the project could be made if there was time for them.

To write a thesis on a start-up company has both pros and cons. The pros are that the company is smaller and, therefore, increases the possibilities for direct communication. We didn’t need to wait to get feedback or answers during the project. The cons are that they have limited resources. However, it didn’t matter anyway because Lund University, which is located close to the company, provided with the resources we needed.