DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Verwer
initials: V.S.O. given name: Varik
student number: 4159098
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD ☐ DfI ☐ SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ☐ Honours Programme Master
specialisation / annotation: ☐ Medisign ☐ Tech. in Sustainable Design ☐ Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: S.F.J. Flipsen dept. / section: D.E. Design for Sustain
** mentor: M.F. Bakker dept. / section: Product Architecture
2nd mentor: H. Stoet
organisation: Audiohuis Delft
city: Delft country: Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair S.F.J. Flipsen date 05 - 11 - 2020 signature

Digitally signed by Bas Flipsen
Date: 2020.11.05 08:53:22 +01'00'

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name date - - signature

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name date - - signature

Initials & Name V.S.O. Verwer Student number 4159098

Title of Project Modulair sound system

Modulair sound system

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 22 - 10 - 2020

03 - 05 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Context

In every household some musical source can be found, for example; a radio, Bluetooth speaker, AV system or hi-fi system. “Music enthusiasts” tend to prefer the latter, a hi-fi system. A hi-fi system is composed of an amplifier, one or more music sources and two speakers, together from now on called a “system”. A system can be placed in the living room, a study, a dedicated listening room or almost any other room in the house. However, the living room is the most common place for a system to be placed, since music needs some “room” and is often enjoyed together. In most cases the living room is a shared space and as a result two or more people have an opinion about the layout and styling. Next to that, they have different priorities, especially if one of them is a “Music Enthusiast”.

Stakeholders

“Music enthusiasts” upgrade or change their system from time to time for diverging reasons. Technical causes can be found in figure 1, however those are not the only reason to make adjustments to a system. More often they seek their ultimate sound, they want to experience and feel the music. They want to hear the individual strings of a guitar being played. Simply put “Music enthusiast” want to reproduce the original sound which was recorded live or in a studio and be touched by the music, feel the musicians emotions. However, since a system is often placed in the living room there are others to account for, with different preferences and interests. The interior styling or color scheme might change from time to time and shapes and forms can get old and out of date.

Audiohuis Delft, owned by Rik Stoet, does not only sell hi-fi equipment, but also develops some themselves. Over the years tube amplifiers, a record cleaning machine, turntables and power management accessories have been designed and produced. This assignment will possibly be used to explore the options for an inhouse developed amplifier. However for now it is just an exploration of the technological possibilities and challenges, next to gaining insight in the wishes and needs of their customers.

space available for images / figures on next page

Initials & Name V.S.O. Verwer Student number 4159098

Title of Project Modulair sound system

introduction (continued): space for images

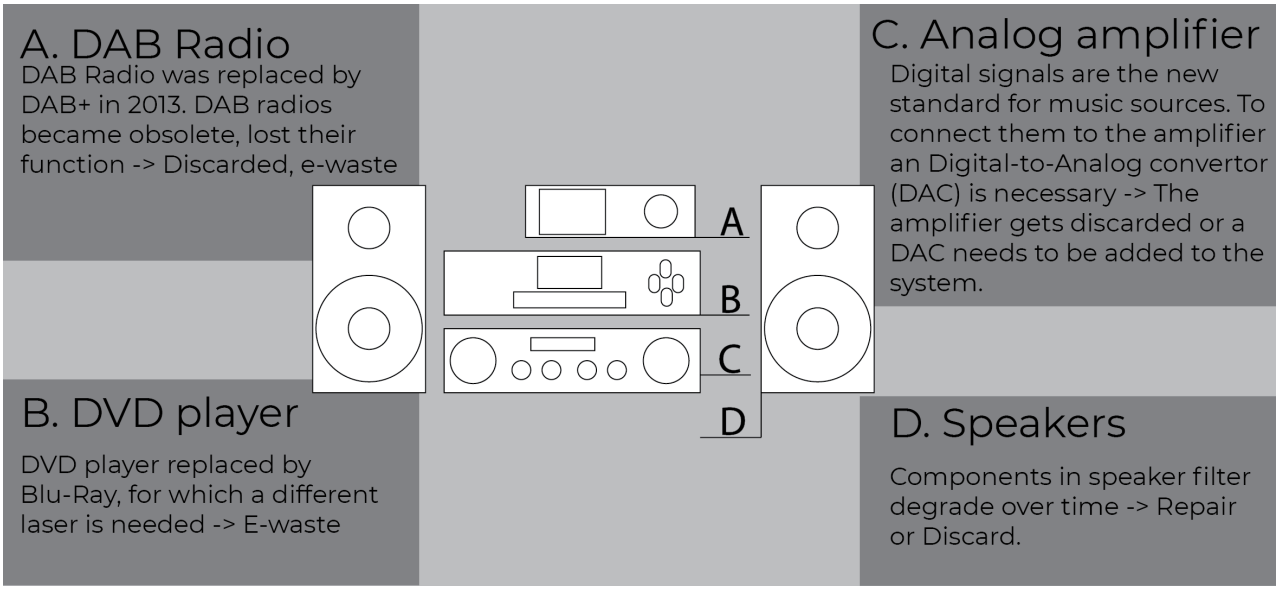


image / figure 1: Problems with current designs, reasons for change or replacement

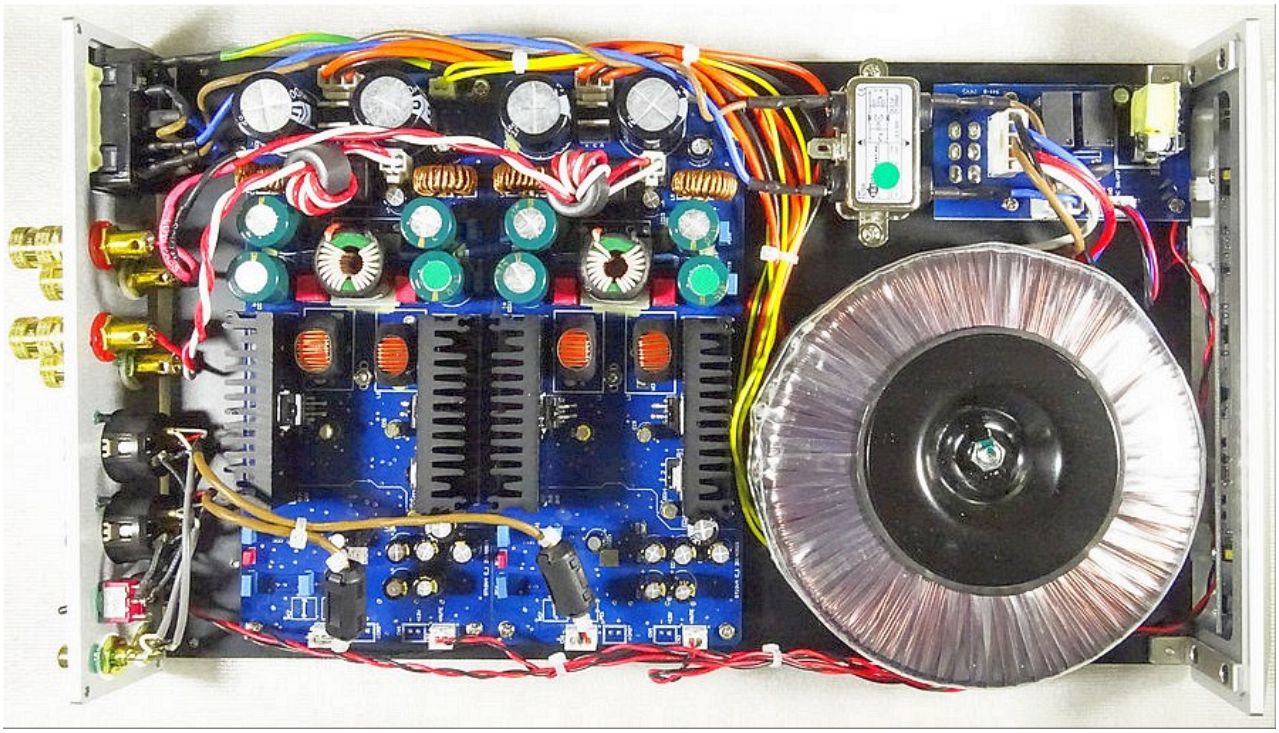


image / figure 2: Everything on one PCB; NuPrime ST10

Initials & Name V.S.O. Verwer Student number 4159098

Title of Project Modulair sound system

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Currently upgrading or changing a system, during a user's "Audio Life"* results in E-waste and is caused by multiple reasons, briefly mentioned in figure 1. These reasons can be: a defect, a technological advancement, a missing function, a change in home interior or the wish for a higher level of performance. (*The period they actively listen to music)
Repair
A broken product, that still meets the desired standard, currently has its problems. Crucial parts are hard to reach, everything is fitted onto one PCB, see figure 2, making it hard to repair, resulting in a total loss product even though the broken part can costs mere cents.
Upgrade
Technological advancements can render a component obsolete, it does not function anymore, or does not meet the users requirements. The addition of a DAC and streaming functions in integrated amplifiers, a development of recent years, make sthem go out of date within years, comparable to mobile phones and computers. Upgrading components is almost never a possibility and even if it is, the removed parts get discarded. There are some brands that use modules to gain additional functionalities, however they are often made for one specific model, not interchangeable.
Context & Performance
Changing your home interior, or the wish to achieve a higher level of performance has the same outcome. Current equipment is discarded, in some cases traded in, and replaced by a completely new system.
Since modules are accepted by the industry, what is preventing them from adopting a complete modular design? A modular design can tailor to specific needs and wishes of the consumers at purchase, but also in later stages. Furthermore, a modular design can increase a systems lifecycle beyond what is currently possible and desirable.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

I am going to reduce the environmental impact of "Music Enthusiast" during their "Audio Life" by designing a "modular integrated amplifier" that is adaptable and can grow along with their needs and wishes, while designing for upgrading, reuse, repair and recycling.

To design for upgrading a suitable modular design will be sought, which has to be accepted by "Music Enthusiasts". The functioning of this product will be proven via a minimal viable product, in which the crucxial points will be tested with users. To stimulate reuse a way to retain value has to be researched, how can parts of the modular amplifier be used by someone else without losing value for the next user. Repairability will be improved by analyzing weak points in current integrated amplifiers. These weak points will be translated into design rules and implemented in the modular design. Design for recycling will focus on fastening methods, material choice and production techniques.
The research questions are:
MAIN RESEARCH QUESTION: What is the environmental effect of adopting a modular design, for a solid state integrated amplifier, in relation to a current upgrade path of a music enthusiast during their "audio life"?
SUB1: What is the environmental impact of current solid state integrated amplifiers?
SUB2: What is the preferred modular design for a solid state integrated amplifier?
SUB3: What is the current environmental impact of a music enthusiast upgrade path during their "audio life"?

With regard to the modular design there are limitations to the extend of the redesign. The final design will not include any way to play a physical medium. PCBs cannot be redesigned on component level, only on architecture level. For example; part of the pre amplifier may be placed on a separate PCB, but the specific resistors of the preamplifier will not be specified.

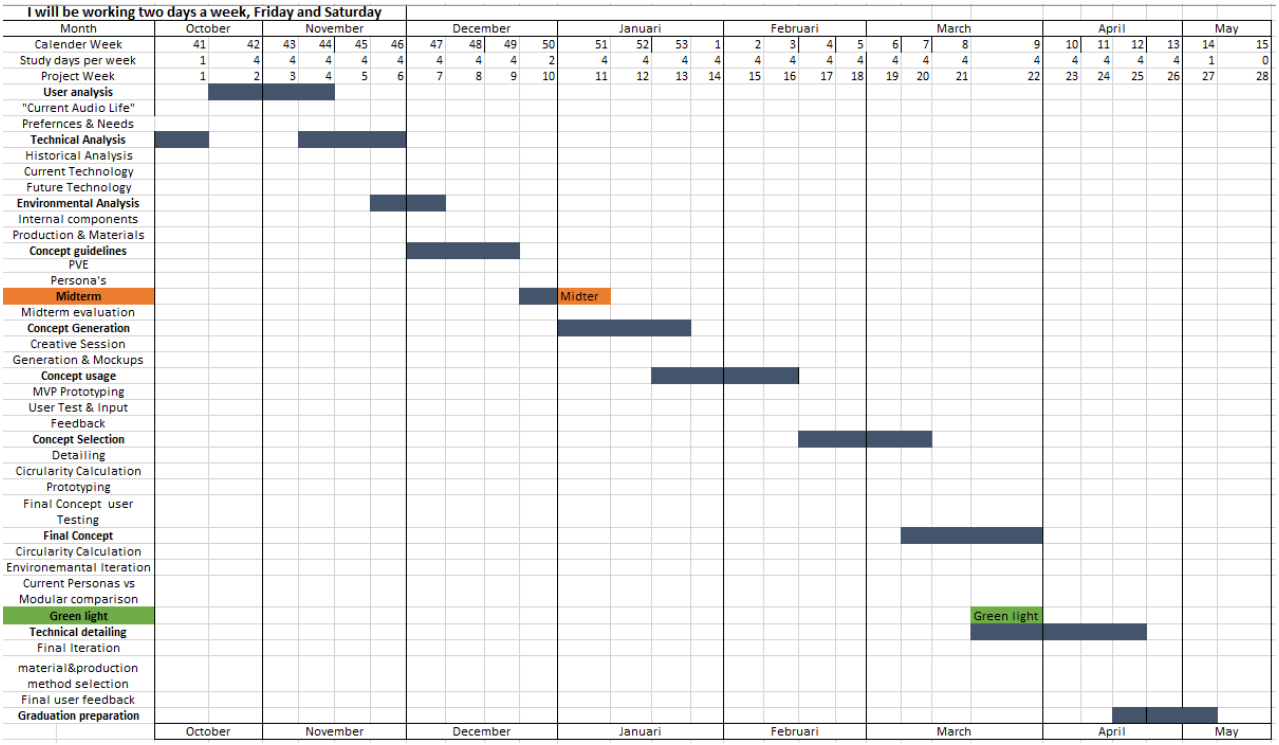
Initials & Name V.S.O. Verwer Student number 4159098

Title of Project Modulair sound system

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 22 - 10 - 2020 3 - 5 - 2021 end date



Technology

I will research the current product designs of integrated amplifiers, their functions, level of integration of the different parts, historical development and repairability. The insights gained will be used to design a new modular system that allows users to change the system to their wishes and needs, without resulting in E-waste. To determine the environmental impact of current designs I will use the in-house developed assessment tool, HMS (hotspot mapping) and ease-of-disassembly. HMS will help determine current hotspots which should be prevented or solved in the modular design. Ease-of-disassembly will provide insights with regard to recyclability and repairability. The latter will be strengthened by field research at Studio 107, an audio repair shop in The Hague.

User

The needs, wishes and preferences of music enthusiast will be researched at Audiohuis Delft and Rik Stoet High End Audio using questionnaires and related research methods. Music enthusiasts, retail employees, repair technicians and brand representatives will be invited to partake in a creative session. This session will be focused on modular design possibilities and functions and functionality of the solid state integrated amplifier. Part of this will be captured in three persona's, the other part in design concepts.

Environment

Current and past modular designs will be analyzed via desk research and where possible by contacting the owners, manufacturers. In this research I will also look at graduation reports available in the depository. The outcome will be translated to design guidelines for the modular integrated amplifier design. To determine the relative environmental impact of the new design compared to current integrated amplifiers I will create 3 or more historical scenarios,1 for each persona. The comparison between the new modular design and the historical scenarios will result in a conclusion whether the modular design is viable, feasible and more environment friendly.

Initials & Name V.S.O. Verwer Student number 4159098

Title of Project Modulair sound system

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

As you can imagine from reading this project brief I am one of those music enthusiasts, currently working at Audiohuis Delft. During my job I have seen many models come and go, with only minor changes but forcing people to change, even if it is only for the appearance of the new model. This is something I want to change, adding the option to grow on a stable foundation. This is also driven by personal motivation, I have had 10 different setups over the years, searching for my personal preference on a budget. I want people to be able to do the same, but without the E-waste I generated during that journey.
During this project I want to prove to myself that I can handle a design project from start to finish. In previous courses I have done this within a team, but I kept doing the same part of the project, the mechanical or the electronical aspects of the designs. The human interaction was something I left for those more "qualified" to study and interpret, however in this assignment I think I am more than capable to succeed in human interaction side of the assignment and learn along the way.
Furthermore I want to increase my knowledge concerning design for re-use and design for recycling. During previous IPD courses Life Cycle Assessments and related topics have been briefly mentioned and studied, but I want to learn more. To do so I want to incorporate the two tools, taught by Bas Flipsen and Ingrid de Pauw in the online course: "Circular Product Design Assesment", in my graduation thesis. These tools are: HotSpot Mapping (HSM) and Circularity Calculator (CC).

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Initials & Name V.S.O. Verwer Student number 4159098

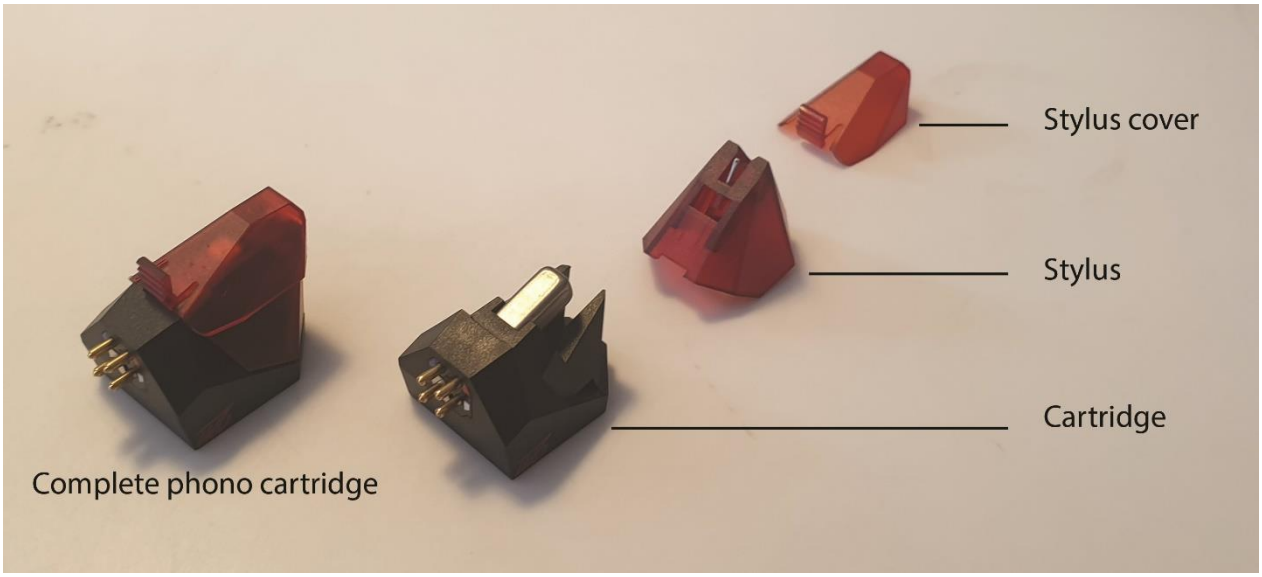
Title of Project Modulair sound system

AES3: AES/EBU
AES3 is the digital variant of a XLR connection. Mainly found in professional recording studios.

Analog
A analog signal is a continuous signal, which can be positive or negative. A analog signal can be visualized as a sinus wave.

Cartridge

A cartridge is a part of a record player. The cartridge holds the stylus that touches the record. It reads the analog information on the vinyl record and converts them into an electrical signal. There are two common types of cartridges; Moving Magnet (MM) and Moving Coil (MC).



Cassette player
A cassette player reads the music from a cassette tape.

Cassette tape
A cassette tape is a , commonly, plastic enclosure that holds a magnetic tape. On this magnetic tape music can be stored, which can be played by a cassette player.

Cd transport
A CD transport looks exactly like a CD player, but misses the analog connection on the back. It can only read the digital data from the cd and send in to an external DAC. It transports the data from the CD to the DAC.

Cd player

A CD player is a CD transport and a DAC in one enclosure. It reads the data from the cd, sends it to the DAC and the analog signal is send to the pre amplifier.

Crossover
A crossover is a digital or passive electronic system designed to split a total frequency range in two or

more frequency ranges. In a two way speaker the lower frequencies are sent to the woofer, the higher to the tweeter.

DAC
A DAC is a Digital to Analog Converter. It converts the binary digital signal to an analog signal. The analog signal can be fed into the Pre Amplifier.

Digital
A digital signal is binary, it is string of ones and zeros. A digital signal can be visualized by square waves. It can be transported using four kinds of cables; Optical Toslink, Digital Coax, USB and AES/EBU.

HiFi solution *(Umbrella term)*

Can Contain a; Preamplifier, Power amplifier, Power Transformer, Streamer, Dac, Phono Pre amplifier, Headphone Amplifier, Room Correction, Equalizer, Tone Control.

Integrated Amplifier
An Integrated Amplifier is a combination of two devices in one enclosure; a Pre Amplifier and a Power Amplifier. Additionally there is a power supply in the enclosure.

Interlink
An interlink is used to connect two devices, for example a pre amplifier and a power amplifier. An interlink can transport a digital or analog signal, depending on the construction and characteristics of the cable. The medium through which the signal travels is copper, silver or an optical conductor.

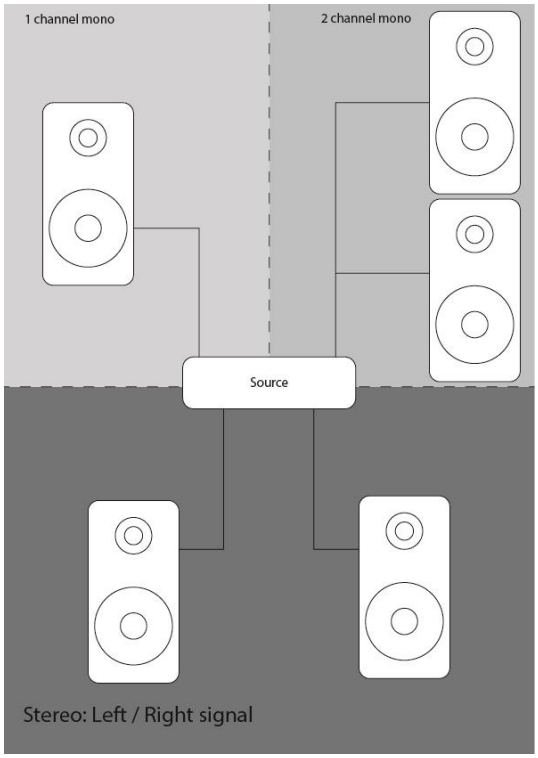
Loudness
Loudness boosts the low frequencies at lower volumes. The human ear has difficulty hearing low frequencies at low volumes. Loudness boosts the low frequencies at low volumes, compensating for the inefficiency of the human ear.

MC Cartridge
A Moving Coil cartridge has a fixed magnet and a moving coil. The moving coil allows for smaller details in the analog path to be picked up, resulting in more detail in the music. In most cases it cannot be directly connected to a phono stage in an integrated amplifier.

MM Cartridge
A MM cartridge can often be recognized by its removable stylus, the needle can be replaced. MM cartridges have a fixed coil, in which the magnet moves. MM cartridges can be connected to a phono input of an integrated amplifier. If such an input is not available a phono stage needs to be used.

Mono

Sound is mono when only one speaker is used.



Pre Amplifier
A Pre Amplifier manages all the connected sources. It allows the user to choose between the cd player and streamer for example.

Power Amplifier
A Power Amplifier is connected to a Pre Amplifier. The signal from the pre amplifier is collected and amplified before sending it to the speakers.

Power connector
A power connector is located on the back of almost any audio device. It can either be a 230V connector or a low voltage connector. In case of a low voltage connector the device is supplied with an external power supply.

Phono preamplifier / Phono Stage
A phono preamplifier is used to connect a turntable to. It amplifies the signal coming for the cartridge, before sending it through to the Pre Amplifier.

Power supply
A power supply is either external or internal. An external power supply can be alternating current (AC) or direct current (DC). An internal power supply can be recognized by an 230V power connector on the apparatus.

RCA/Chinch/”Tulp”
Is the standard connection terminal to transport data between audio devices. The connector can be used for digital and analog signals.

Receiver
A receiver is a combination of three devices in one enclosure; a Pre Amplifier, a Power Amplifier and a Tuner.

Speaker terminal
A speaker terminal is located on the back of an integrated, power amplifier and speaker. A speaker cable can be connected to the speaker terminals, to connect the speakers to the amplifier.

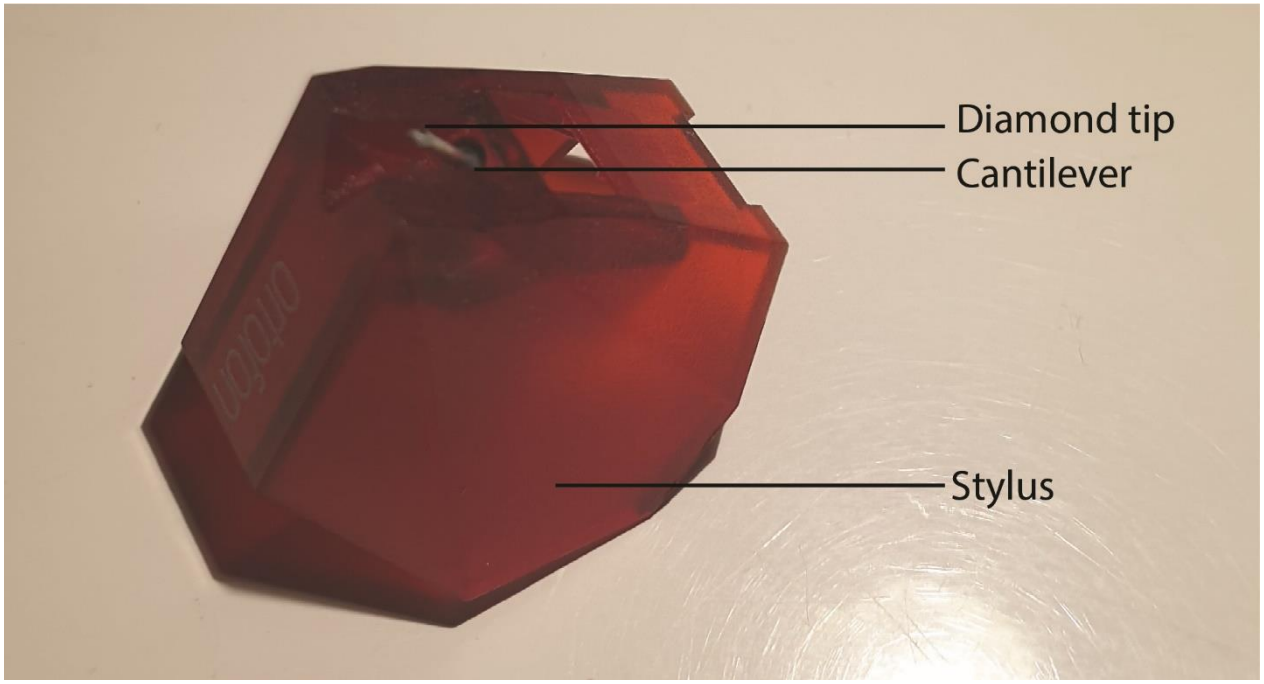
Stereo

Stereo sound uses two speakers, one on the left and one on the right. Stereo sound seems to come out of nowhere and places the music in between the speakers. Placing the musicians there where they were in during recording.

Sources
All devices that produce music are called sources. For example a cd player, record player, streamer or tuner.

Streamer
A streamer can download music from the internet and immediately play it. A streamer has digital outputs, coax or optical. Additionally a DAC can be integrated, which gives the streamer an analog output.

Stylus
A stylus is part of a MM cartridge, it holds the needle. The stylus slides in the MM cartridge.



Tuner
A tuner is used to listen to radio. It can either be digital radio or analog radio, depending on the method used. Digital radio is called DAB+ and analog radio FM or AM.

Turntable/ record player
A turntable can play 7, 10 and 12inch vinyl records. It needs to be connected to a phono preamplifier, integrated in an amplifier or as a separate.

Tweeter
A tweeter is a type of speaker driver, designed to reproduce the higher frequencies. Their frequency range is typically between 2kHz and 20kHz.

Tone Control
Tone Control allows the user to tweak the sound to their liking, amplifying or attenuating specific frequencies. The most common use is adding or removing bass and treble.

Volume control

Volume control is a function of the pre amplifier, it limits the signal that is fed through to the power amplifier. It gives the user control over the sound volume, in the analog or digital signal path.

Woofer
Speaker woofers are designed for the mid to lower frequency range. They typically handle a range from 50Hz to 2kHz, however there are woofers who go up to 5kHz.

XLR terminal
A XLR terminal allows XLR interlinks to be connected. XLR cables are balanced, allowing long cable lengths.

XLR Interlink
A XLR Interlink is a balanced cable. The main benefits are the option to use long cables without signal loss and reduces susceptibility to external influences caused by electromagnetic interference.

Appendix C – HiFi system components in detail

Preamplifier

A preamplifier is part of every HiFi system, it manages incoming and outgoing signals. Preamplifiers can be designed using multiple product architectures and principles. The most basic preamplifier is a passive preamplifier, capable of controlling the volume of one source before sending it through to the power amplifier. The most advanced is a digital DSP preamplifier, having multiple functionalities in one. The following chapter gives an overview of the main functionalities of a preamplifier, the different types of preamplifiers and the features they can have.

Figure X: High-End Audiophile, hand build, passive pre amplifier.

Main Functionalities(s)

The main functionality of a preamplifier is collecting the analog signal from a source, allowing for user input, and sending the signal through to a power amplifier. The preamplifier adjusts the output signal, of which the level is determined by the user, using a volume control.

A secondary, but common, functionality is source selection. This allows the user to connect multiple, analog, sources to the preamplifier, of which one can be selected and put through to the power amplifier

Preamplifier architectures

In the previous section the functionalities and features of preamplifiers have been discusses. In this section we will one step back, and briefly look at the different architectures of preamplifiers. The current preamplifiers available can be differentiated into three main categories: Passive, Active and Digital preamplifiers. Passive and Active preamplifiers are both designed to work with analog signals. Digital preamplifiers are designed to work with digital signals. They all fulfill the same function in their own way and have their benefits and drawbacks.

Passive

Passive preamplifiers do not have to be connected to an external power source. They collect the line level signal from a source and can only attenuate that signal. There are variant available with either one or multiple inputs and the same is true for the outputs.

Since there are no active components, the volume is controlled by a variable resistor. As a result the signal going in and out is practically the same, if not attenuated, without any artificial artifacts picked up along the way. This unaltered signal is preferred by some Music Enthusiasts.

Active

Active preamplifiers are characterized by their need for an external power source. They can attenuate the signal coming from the source, but can also amplify this signal. The latter cannot be done by a passive pre, same goes for tone control, which can be part of an active pre. Finally an active preamp can resolve a mismatch in input and output impedance of the source and the power amplifier.

Digital

A digital preamplifier is designed to work with digital signals instead of analog signals. They can have analog inputs, however in most cases they will be converted to digital signals using an Analog to Digital Converter, ADC. Digital signals can be manipulated using computing power, making it possible to correct for room acoustics, and replace a passive speaker filter with an digital filter, crossover.

Pre amplifier Features

Tone control

Tone control is a set of input parameters that can be adjusted by the user. The parameters are equalization and balance. Equalization can be subdivided into Bass/Mid/Treble control and Loudness .

Bass/Mid/Treble controls amplify or attenuate parts of the frequency spectrum to the users wishes. Loudness amplifies the lower frequencies at lower volumes. Loudness is designed to compensate for the inefficiency of the human ear, which is less sensitive for low frequencies at low volumes.

Balance control changes the loudness coming out of the speakers. It attenuates the left or right channel, allowing the sound image be centered if the speakers are not symmetrically placed, or if the listener is not sitting somewhere in the middle.

Figure X: Marantz Model 3200 Pre amplifier, with tone control.

Optional Pre amplifier functions

In the previous paragraph the two main functionalities of the preamplifier are discussed. In this section optional features of the preamp are briefly discussed. What do they do, when are they used and what are the benefits for the user. These features can be part of an pre amplifier, but they don't have to. These features are also available as separate HiFi equipment.

DAC

A digital to analog converter converts a binary digital signal into an analog signal. The string of digital ones and zeros are converted in an analog signal. This analog signal can be fed into the preamplifier. A DAC is needed when a user wants to connect a digital source to their system. Digital sources can be a CD-transport, a streamer or a tv.

Figure X: Audiolab DAC & Headphone amplifier.

All digital devices with an analog output have a DAC built in, however there are differences in the way they convert the digital signal into analog. The precision by which the DAC converts determines the final accuracy of the sound coming out of the speakers.

Phono pre amplifier

A phono preamplifier is needed to connect a turntable to a HiFi system. The phono preamplifier boosts the output signal of the phono cartridge before it is send through to the pre amplifier. To correctly amplify the signal two parameters are used, capacitance loading(Ω) and resistance loading (pF), both depend on the type of phono cartridge used. In table X the general values for a moving magnet(MM) and moving coil (MC) cartridge can be seen.

Figure X: Project Tube Box DS2, MM/MC Phono Pre amplifier.

	MM	MC
Capacitance Loading (Ω)	100pF	0pF
Resistance Loading (pF)	47k Ω	100 Ω
Gain Level (dB)	40dB	60dB

Table X; Difference between gain and volume is explained in Appendix X

The values in table X are generally fine, however to make your system perform at its maximum greater control can be wished and needed. This greater control can be found within all three parameters and can therefore be specified on more advanced and better performing phono preamplifiers.

Gain vs Volume

Gain means the decibel input in a system. Gain is used to control the loudness of the input signal, before processing.

Volume means the decibel output of a system. Volume is used to describe the loudness coming out of the speakers.

In home HiFi systems gain is only used in two situations, when using a turntable or when recording music. Gain is needed to amplify the signal from a phono cartridge to line level. During recording, using a cassette or tape deck, gain is used to set the input level of the recording.

Phono Cartridge

Phono cartridges come in all kinds of shapes, sizes and prices with their own characteristics. In this report all types of cartridges will be reduces to two, Moving Coil (MC) and Moving Magnet (MM), see figure X for examples. These are the two most common types of cartridges, and the two types sold at “het Audiohuis”.

Differences

MM cartridges are, usually, the cheaper option between the two and can be recognized by the replaceable cantilever/stylus. As the name suggests the magnet is moving since it is attached to the stylus. The magnet moves between two coils, as can be seen in figure X. MM cartridges typically have an output voltage of a few millivolts, 3-5 mV.

Moving Coil cartridges are the more expensive ones and have a fixed stylus. Where a magnet is attached to the cantilever in a MM cartridge an MC cartridge has a coil attached. The coil moves between two fixed magnets, see figure X. MC cartridges generally have an output voltage of about 0.3mV

The different manufacturing processes, needed to make a MM or MC cartridge, explain a big part of the prices difference between them. Furthermore are MC cartridges made to tighter tolerances.

Detail

MC cartridges are capable of reproducing more detail than MM cartridges. This is due to Newton’s second law: F=m*a. The magnet attached to a MM cantilever has more mass than the coils attached to a MC cantilever. The greater mass of the MM cartridge results in a longer reaction time, missing details in the vinyl.

Conclusion

MM cartridges are more affordable than MC cartridges. This combined with the fact that the needle can be swapped of an MM cartridge makes them the first choice for starters. However later on they might become more demanding, wanting to switch to an MC cartridge. Therefore the phono pre amplifier needs to be adjustable or swappable. Furthermore, in case of a MC preamplifier is used, the controls must be accessible by the user or the retailer.

Decibels

Decibels are $1/10^{th}$ of a Bel, named after Alexander Graham Bell. Decibels have no absolute value, but it expresses a ratio. Decibels use a logarithmic scale, instead of a linear one. Doubling the volume is an increase of 6dB and doubles the voltage to the previous situation. Decibels are always relative to a previous situation. If the sound level is -20dB, it is 20dB lower than previous and the sound level is a factor 10 lower. 40db is a factor 100 bigger.

Headphone amplifier

Headphones are basically two small speakers in an enclosure to fit in your ear or to rest on your ear. A headphone amplifier allows you to connect your headphones to the preamplifier, making it possible to listen to all the connected sources.

Figure X: Lehmann Rhinelander

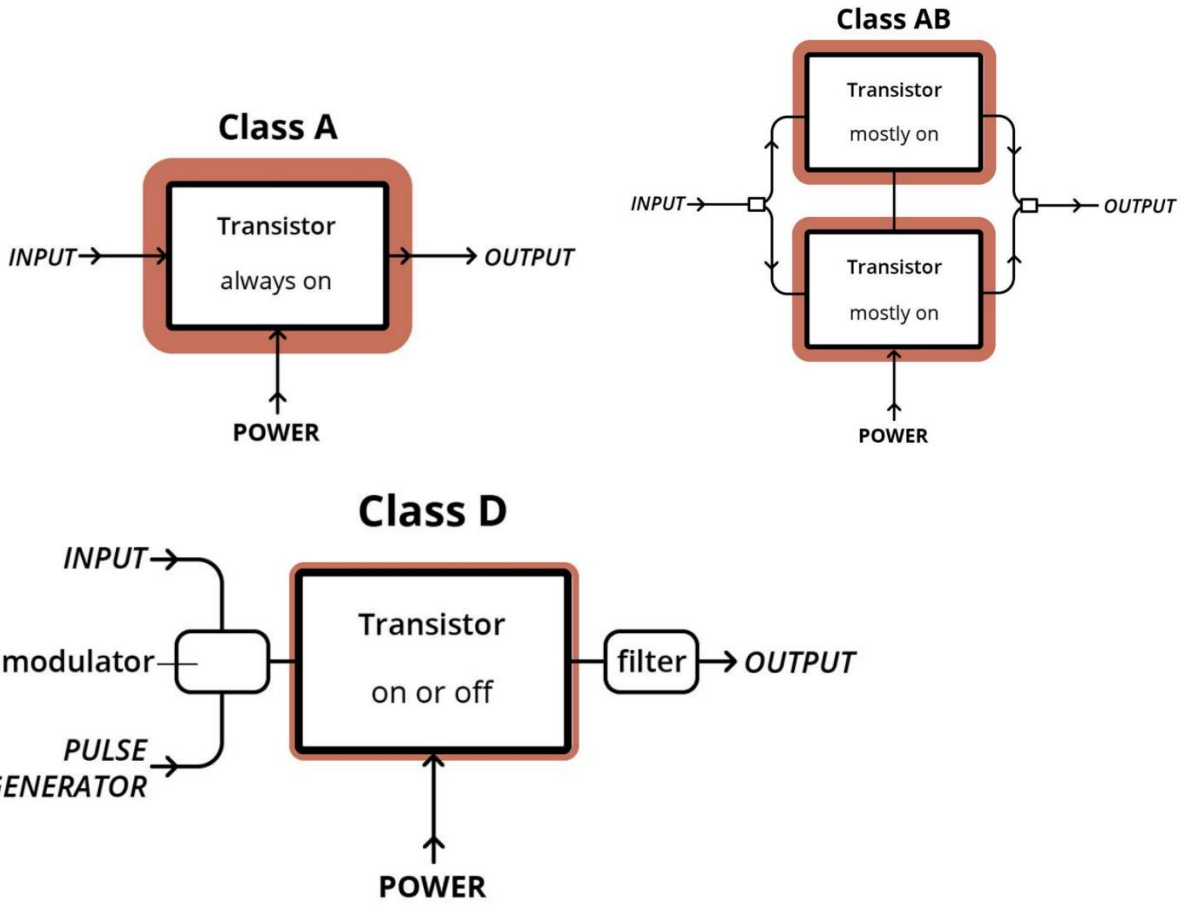
Streamer

A streamer can get music files from different musical sources, e.g. Spotify or Tidal, by downloading them via the internet. They can play these files and afterwards delete them immediately. Streaming does not require an entire album to be bought, offering a vast amount of music to the user.

Figure X: Bluesound Node 2i streamer

3.2.5 Power Amplifier

Class A: Transistors are always on, no delay between switching on and off. Highest fidelity sound, most energy used, biggest cooling needed.



Power supplies

Linear power supplies

Switching Mode Power Supply

- Schakelende voedingen kunnen makkelijker van vermogen wisselen, en zijn efficiënter. Ze creëren alleen het benodigde vermogen. Daarnaast zijn ze goedkoper te produceren omdat er minder koper in wordt gebruikt. Nadeel is dat ze in de huidige vorm sneller stuk gaan, doordat de gebruikte elco's warm worden en maar een bepaalde levensduur hebben.
- Een apparaat met een afstandsbediening heeft sowieso een schakelende voeding. Deze voeding wordt gebruikt om te kijken of er een signaal naar het apparaat wordt gestuurd. Schakelende voeding heeft zeer laag verbruik, 0.5w of minder. Apparaten die niet meer aan gaan hebben vaak een defecte schakelende stand-by voeding.
- Yamaha stand by voedingen staan er om bekend dat ze stuk gaan, standaard liggen.
- Schakelende standby voeding wordt gebruikt zodat de hoofdvoeding wel compleet uit kan.

Toroidal Core transformer

- Ringkern transformator wordt berekend en gemaakt om een bepaald vermogen te leveren. Voordeel is levert schonere stroom, mooi sinus vormig en levert daardoor betere geluidskwaliteit.

Step down transformers.

Appendix D – Background information of Audiohuis Delft. associated stores and previously developed HiFi related products.

Audiohuis Delft

Audiohuis Delft was founded in 1999 by Hans Pronk, a former TU Delft Architecture student, who worked at Multiphone before starting his own business. About five years ago the shop changed location, and ownership, but Hans is still around.

Figure I: A glass wall separates AHD into two spaces, store in front, listening room in the back.

AHD is filled with a wide variety of HiFi brands and product categories. Tube amplifiers and turntables may be old technology, but are still part of the shops inventory, supplemented with newer kinds of equipment like solid state amplifiers, DACs, streamers and active stereo speakers. Anything that one may need in their HiFi system is either available, or could be provided. Upon entrance customers are welcomed by a domestic feeling space, with a wooden floor and designer furniture, as can be seen in figure II.

Figure II: Even though it gets a bit messy from time to time, everyone feels welcome.

Employees

As mentioned the store is run by Rik, fulltime supported by me, Varik, and Hans during the Saturdays. Rik has a specialized knowledge of record players and tube amplifiers and even designed and produced them, as can be seen in appendix B. Hans, has an enormous musical knowledge and experience in selling HiFi equipment and helping customers discover what they really seek. Finally there is me, I learn about HiFi while working there and simultaneously help Rik develop his many side projects. We focus on stereo equipment, bringing a musical reproduction into peoples' homes, but do not evade other technical questions.

The Hague

Besides Audiohuis Delft there are three other shops owned by Rik. Rik Stoet High End Audio, see Figure III, VinylVinyl, and Studio 107, all located in the centre of The Hague. Rik Stoet High End Audio is comparable to the shop in Delft, see figure III, but with a slightly different inventory. It has been in the same location for 25 years and is managed by Frits. Located in the store there is a second small shop, VinylVinyl, selling vinyl records and accessories. Zhen manages this part of the shop, from start to finish, both online and offline, with an international customer base.

Figure III: Some other brands, but equally messy and comfy.

Demo room

Two thirds into AHD customers are stopped by a glass wall, creating a separate space. In the Hague this space can be found at the first floor, the stairs leading there can be seen in figure III. These space are also known as a Demo rooms, or in Dutch “luisterruimtes”. The purpose of these rooms is to let customers experience different setups, making different combinations of equipment to let them discover their preferred “sound”. In Figure IV the demo room of Rik Stoet High End Audio can be seen.

Figure IV: A plenitude of speakers and other HiFi equipment packed into the Demo Room, offering “unlimited” combinations to fulfil everyone’s needs and wishes.

Studio 107

Studio 107 is, as mentioned, also located in the Hague. Studio 107 is run by Niek, who is now working there for 25 years. He started working there during his Electrical Engineering study at the TU Delft. Studio 107 focusses on repairs of vintage and 'new' but broken-down HiFi equipment, almost all executed by Niek. In figure V two repair stations can be seen, equipped with all possible equipment to test, measure and repair. Next to repairs the shop is also a 2nd hand store, see figure VI, selling used, traded in, and customers old stereo equipment and speakers. Finally Niek determines trade in values offered at both Audiohuis Delft and Rik Stoet High End Audio.

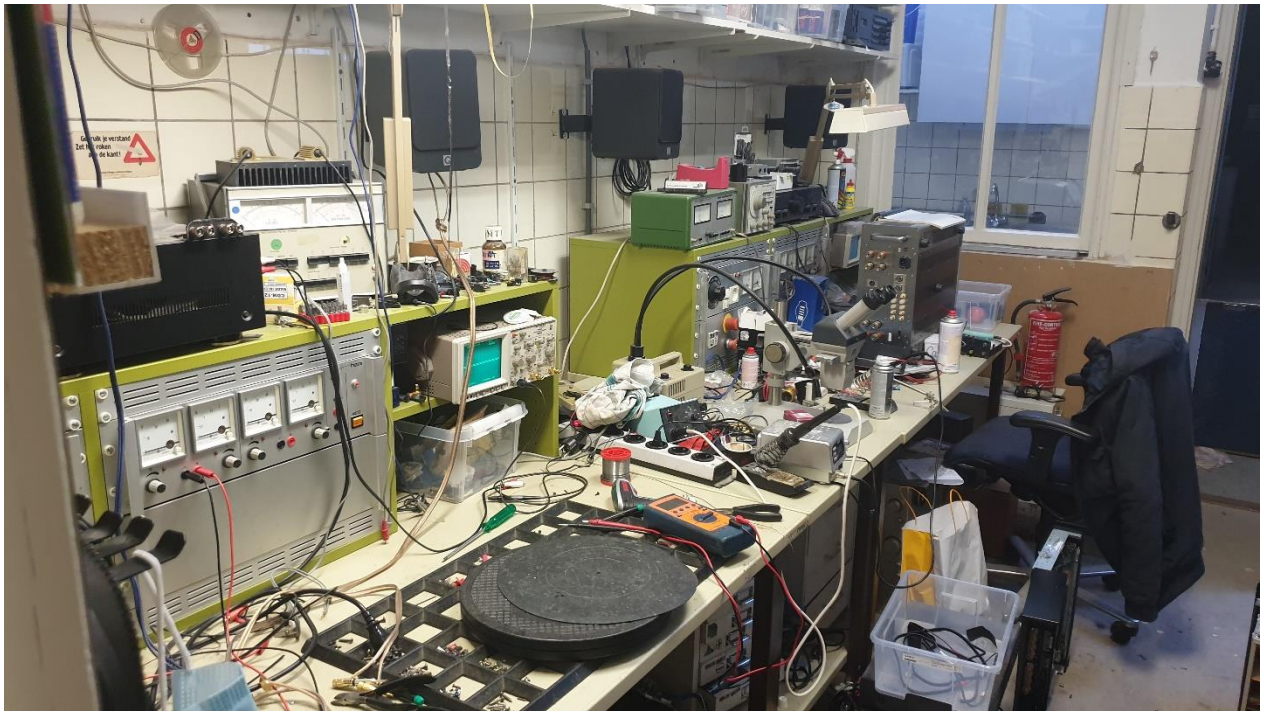


Figure V: Repair department of Studio 107, equipped for two employees.

Figure VI: Studio 107; Traded in equipment displayed along the shops walls.

HiFi related products

Heart - Stoetkit – Tube Amplifiers

Figure VII: Stoetkit 6.

Heart was one of Rik's first companies. He designed and fabricated multiple tube amplifiers, ranging from integrated amplifiers to separate mono blocks (single channel power amplifiers) and pre amplifiers. Some of these amplifiers could be bought as a kit, everything included but assembly is up to the owner, or pre-assembled.

Essential Audio Tools – Power management Solutions

Figure VIII: Mains multiplier 5 with a Sound Saver, Noise Eater, Pulse Protector and Current Conductor L.

Essential Audio Tools produces power management cables and accessories. The company was started by Rik, but is currently run and partly owned by Leon. The company is located in Rijswijk, where development, production and shipping is being taken care off. (Essentialaudiotools, n.d.)

Takumi – Turntable

Figure IX: Early version of the Takumi Turntable TT Level 2.1

The Takumi turntable has been developed over a period of 4 years. It started with modifications to an existing and available turntable. Step by step all the parts were redesigned with the Takumi TT2.1 (AC & DC) as a result. The goal of this turntable was originally to show the capabilities and knowledge of AHD & Rik Stoet High End Audio. However, this goal shifted to offering a high performance turntable, for an reasonable price. Therefore expensive surface treatments, like polishing, plating and anodising are not part of the design. Resulting in a turntable that outperforms anything in its price range (Jonker, 2019).

Watsons – Record Cleaning Machine

Figure X: Record cleaning machine for every diameter record.

The Record Cleaning Machine is produced, assembled and packed in China and distributed by Monitor Audio Nederland. The design shines in its simplicity, a vacuum cleaner motor sucks the dust, captured in a cleaning liquid, of the vinyl records. The platter on which the record rusts is a bit smaller than the record itself, making sure the “bottom” of the record does not get wet again after just being cleaned. The enclosure is made of anodized aluminium parts, that slide into each other, designed for quick assembly and disassembly. All parts can be replaced, if necessary, by removing the bottom cover, and are readily available.

Appendix E– E-waste in detail

Growth

Over the past 20 years the amount of E-waste worldwide has tripled. This growth is caused partly by emerging economies in Asia and Africa, combined with new product developments. Traditionally "passive" products are turning into smart products, equipped with electronic sensors or other forms of electronics. The clothing industry is a prime example; yoga pants that improve your pose via haptic feedback, or a jacket that lets you control your smartphone by touching your sleeve (Lifewire, 2021). No matter the cause, currently these factors result in an average worldwide growth of 2.5 million Mt (million metric tons) of EEE annually (Forti, et al. 2020).

In the same year, 2019, a worldwide total of 53.6 Mt E-waste was generated. Divided by the world population this comes down to 7.3kg of E-waste per person. Of this 53.6Mt only 17.4% is accounted for via the regulated recycling infrastructure. The other 82.6% is uncertain, it is discarded via household containers, exported as second hand, illegally exported or dumped (Engels, 2020), see figure XII.

Opportunities

The enormous pile of E-waste that is uncertain holds a tremendous value. It is estimated that the E-waste of 2019 had an raw materials value of approximately $57 billion (Forti, et al. 2020).

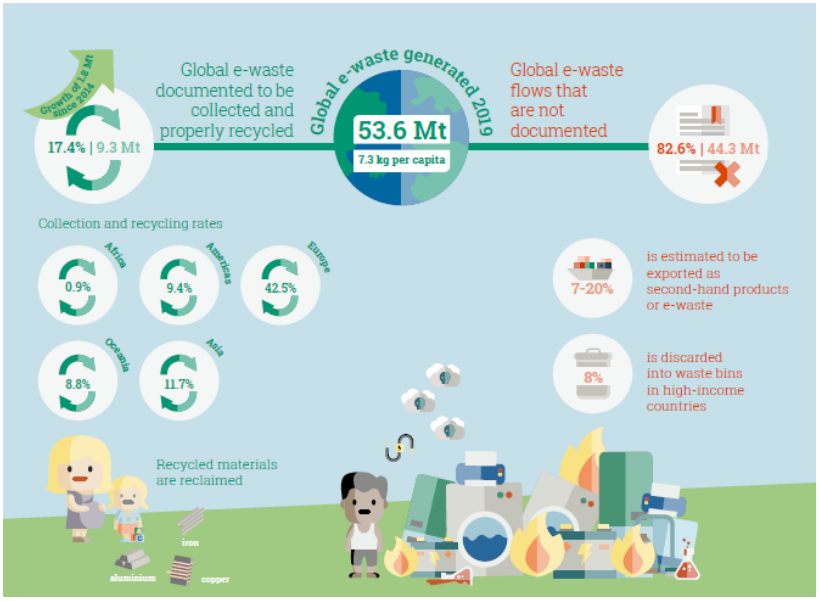


Figure XII: Estimations of uncertain E-waste (Forti, et al. 2020. P14).

The Netherlands

The growth is not only worldwide caused by emerging economies, the amount of EEE and WEEE in the Netherlands is also increasing. In 2018 a total of 514 kt of EEE has been put on market, an increase of 33% since 2010 (Baldé, et al. 2020). The category, to which HiFi equipment belongs, small equipment, see figure XIII, has grown by 12%, to 126kt.

The amount of WEEE generated has increased by 13% since 2010, to 366kt. 29.5% of 366kt is part of small equipment, 126kt. (Baldé, et al. 2020). In the Netherlands this resulted in 19kg, on a total of 490kg, of electronic waste per person in 2018. (Milieucentraal, 2018).

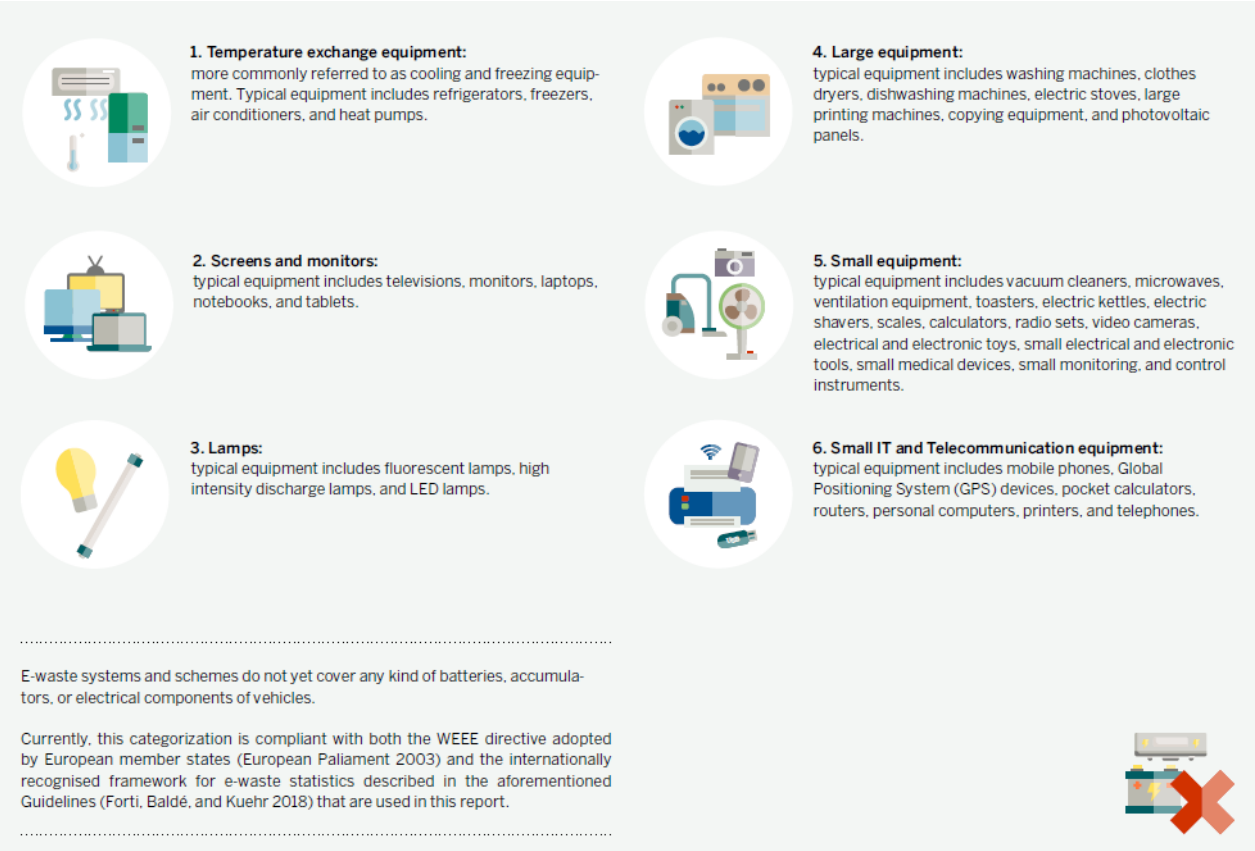


Figure XIII: Categories of WEEE (Forti, et al. 2020)

HiFi equipment

To determine the percentage of HiFi equipment, of the 19kg electric waste , more detailed datasets are needed. Even though that available scientific reports suggest that these datasets do exists, they were untraceable. Therefore a substation was used, based on a research conducted in the United Kingdom.

Kerbside collection

In 2008 a nine week trial was conducted in Bury St Edmonds, Suffolk (Wrap, 2009). During the trial small E-waste was not collected at recycling points, but collected from the kerbside. The goal of this trial was to determine the percentage of E-waste that could be rescued from the household waste containers (known as kliko's in Dutch). The conclusion was that this method of small E-waste collection had the potential to increase the amount of recycled E-waste, a positive result, by reducing the amount of E-waste that is disposed via household waste containers. More importantly, this trial did generate the dataset needed to get an indication of the amount of HiFi equipment discarded within the category of small equipment.

Projection to the Netherlands

To counter the fact that no specified datasets from the Netherlands are found, concerning the composition of E-waste, the data gathered in Suffolk will be used as a substitute dataset. The dataset is 12 years old, however it will be used as if it is from today and from the Netherlands. By doing this the data can only be under estimated, not over, due to the increase of EEE and WEEE in the past 12 years.

Amount of HiFi Discarded in the Netherlands estimation

Over a period of 9 weeks 1761 representative small E-waste items were collected.
Of these 1761 items, 33 items are categorized as HiFi-units.

$33/1761*100\% \approx 2\%$

During the trial in Bury St Edmonds about 2% of the kerbside collected small E-waste was Hifi equipment.

Projecting the findings from the UK in 2008, to the Netherlands in 2018 results in 380 grams of HiFi E-waste, per person. (Wrap, 2009).

2% * 19kg = 380 gram. Per person per year.

Appendix F – Hotspot Mapping, Design & Materials

Usage

In this research Hotspot Mapping (HSM) will not be used to redesign a product, but to design a whole new product. By HSM an integrated amplifier the crucial parts within that amplifier are specified. However, whereas all amplifiers are, more or less, build and designed using the same techniques the findings from this amplifier are generalized to all amplifiers.

Process

HSM is an gentle disassembly method, products are disassembled step by step. After each disassembly step the possible next steps are mapped. This process is continued until all parts and subassemblies are separated.

Lets take a two layer box of chocolates as an example. First the ribbon is undone, next the flaps are opened, then you can take out 1 of 8 chocolates. However, you have to take all 8 out to remove the separating layer to get to the next 8. Cutting out the bottom to get to the bottom 8 chocolates would be destructive disassembly, this is not an option in HSM.

The disassembly sequence is filmed using a camera on a tripod, filming straight down. In figure X an image from the recording can be seen. The recordings are used to later on fill in the Hotspot Mapping Datasheet and later on to determine the disassembly sequence. ‘Hotspot Mapping for product disassembly; a circular product assessment method’ (2020) describes the full theory of HSM in depth.

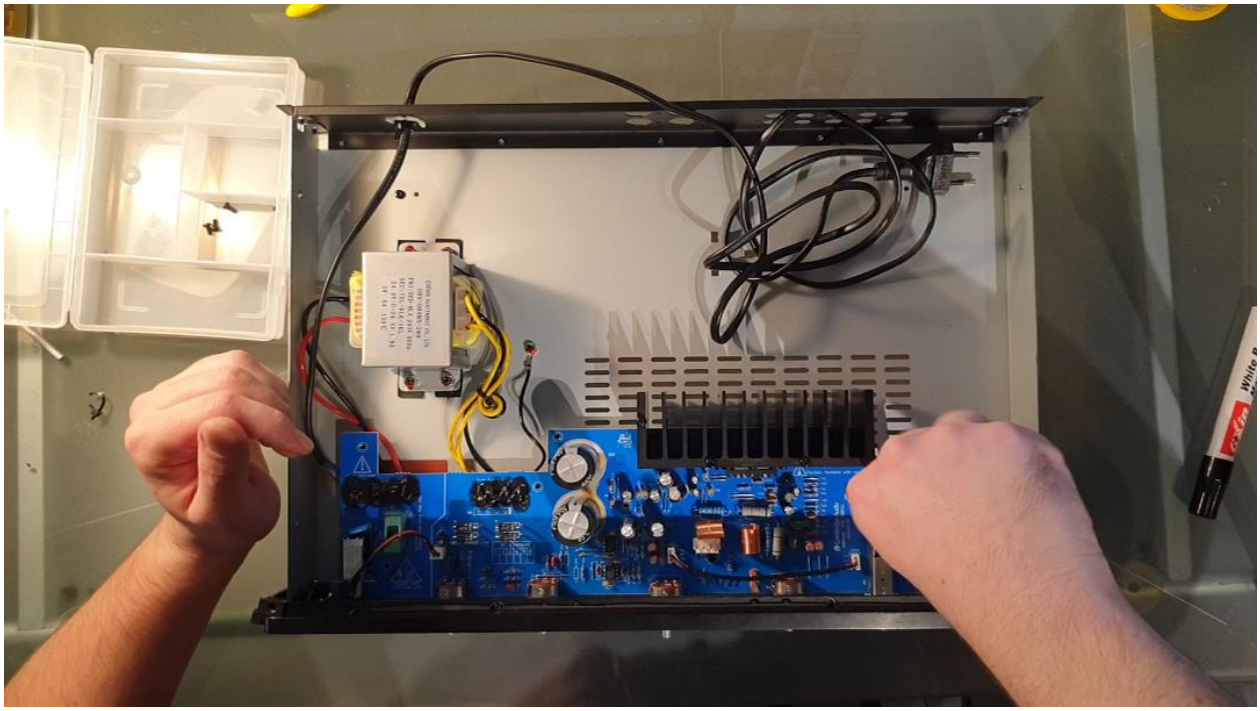


Figure X: Cambridge AM5 disassembly, filmed using a tripod.

Cambridge AM5 - results

The Cambridge AM5 was the most affordable integrated amplifier offered by Cambridge Audio (Cambridge Audio, n.d.). It was available at AHD for disassembling, however it had to be put together again at the end, therefore some “destructive” steps have been skipped, like desoldering the power cables. This step was skipped because the cables were fixed in place using some sort of tar, which couldn’t be removed.

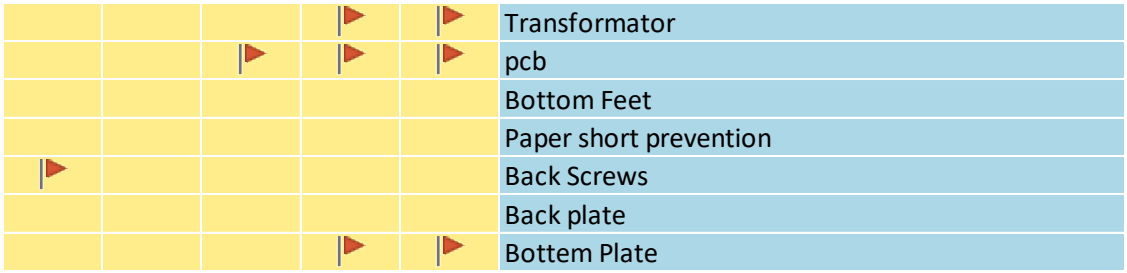


Figure X: The bottom plate has a weight of 1.1Kg and there are 9 back screws.

The PCB and the transformer are crucial for the amplifier to work, but in case of a defect there are 4 disassembling steps needed to replace the Transformer. To replace the PCB the whole amplifier needs to be disassembled, as can be seen in figure X. The steps required to get to each part can be found in appendix R as well.

Time	Activity	Priority part	Environmen	Economic	Notes
					Volume Knob Ass
					Function Select Ass
					Speaker Connector
					PCB Unit
					Volume housing
					Volume indicator
					Function housing
					Function indicator
▶					Top Cover screws
			▷	▷	Top Cover
					Screws Speaker
					Speak PCB Con
					Speaker Terminals
					Input Con Screws
					Input PCB Con
					MP3 Input ass
					Input MP3 Con
			▶	▶	Input Connectors
					Thread Rough Screw Plastic Side
					Fine Thread Screw plastic side
▷					Front PCB Casing Screws
▶					PCB Screws
					PCB Screws
					PCB unit
▶					PCB Frontplate screws
					Plastic Sides
			▶	▷	Front Casing plate
					ON/Off light screw
				▷	ON/Off light disconnect
					MP3 input ass
					MP3 Input ass screws
					MP3 brackets
			▷	▶	MP3 PCB
					Empty speaker terminals
▷					Potmeter nuts
					potmeter rings
					internal front plate
					ON Off knop
					PCB Heatsink small screw
▷					PCB Heatsink big screw
					PCB Heatsink small
			▷		PCB Heatsink big screw
▶			▷	▷	PCB Soldered connections
▶	▷				Bolt/Nut Transformator
▷					Bolt/Nut Groundwire
			▶	▶	Transformator
		▶	▶	▶	pcb
					Bottom Feet
					Paper short prevention
▶					Back Screws
					Back plate
			▶	▶	Bottem Plate
					Feet pads
▷					Feet base
					Rubber pads transformator
					Foam Top Plate

Figure 1: Overview of HSM result of the AM5 integrated amplifier

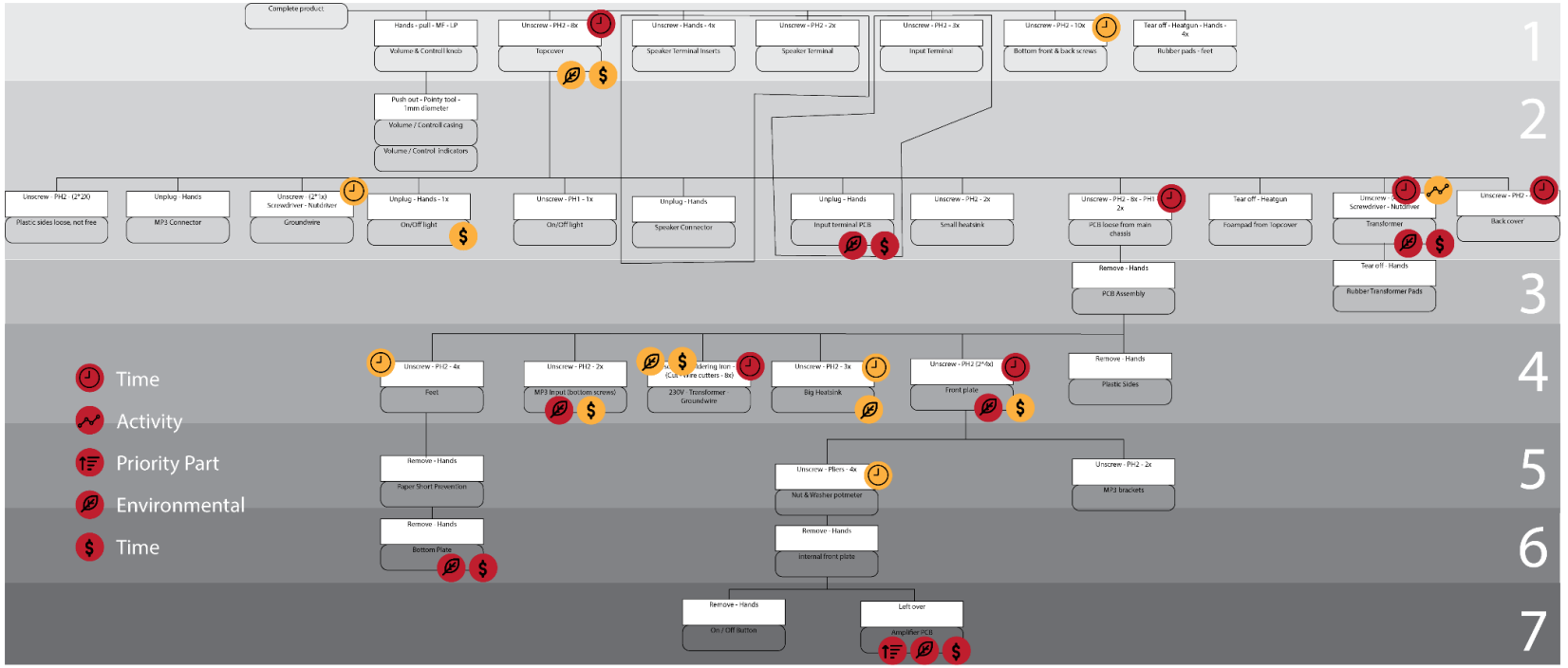


Figure 2: Disassembly steps, parallel and sequential.

Figure 3: Time flags removed, as noted by Flipsen et al, the Philips table was more accurate and suitable.

Findings

- Screws take time to undo and fasten again, but can be reused indefinitely.
- The front plate needs to be removed to get to the PCB.
- The usage of Loctite slows down the replacement of the transformer. Force needs to be applied on the top and bottom side of the enclosure, using tools.
- The power cables are soldered to the PCB and covered by some sort of tar, and soldered from the bottom. The tar is difficult/impossible to remove and reuse. Resoldering the power cables requires some fiddling, if possible at all.
- The strain relief of the power cable is glued in place, impossible to undo and reuse.

Conclusions

Reusable connections should be used where possible // reusable connections are minimized
Removal of critical parts should be as easy as possible // Critical parts can be removed with only readily available tools
The usage of Loctite should be minimized // Loctite is not used
Soldered connections should be accessible // Soldered connections are minimized
Power cables should be removable // Power cables have an external connector

Materials & Design

"By designing EEE that contains parts that are easily separable, constitute recycled metals, and are not hazardous, it is possible to prevent waste generation at EoL. It is important that EEE manufacturers shift from a planned-and-perceived obsolescence design and that consumers demand more-durable products. Manufacturers should also be encouraged to design products that are easily reparable and that allow for faulty components to be easily replaced. In addition, recycling and reuse would be more easily achieved if manufacturers were obligated to meet extended producer responsibility objectives. Currently, EEE is not designed with circularity in mind, but instead linearity, which fails to support prevention, reduction, repair, recycling, and reuse and instead supports a "throwaway society."" (Goodship, et al. 2019)

In the design phase EoL should already be in mind. Materials with a high environmental impact should be avoided, and if needed they should be separable to aid recycling and proper disposal.

Conclusion

- Permanent joining of different materials should be avoided where possible
- Hazardous materials should be avoided where possible

Critical Raw Materials

"Critical Raw Materials (CRMs) are those raw materials which are economically and strategically important for the European economy, but have a high-risk associated with their supply. Used in environmental technologies, consumer electronics, health, steel-making, defence, space exploration, and aviation, these materials are not only 'critical' for key industry sectors and future applications, but also for the sustainable functioning of the European economy." (CRMAlliance, n.d.)

Antimony	Fluorspar	Magnesium	Silicon Metal
Baryte	Gallium	Natural Graphite	Tantalum
Bauxite	Germanium	Natural Rubber	Titanium
Beryllium	Hafnium	Niobium	Vanadium
Bismuth	HREEs	PGMs	Tungsten
Borates	Indium	Phosphate rock	Strontium
Cobalt	Lithium	Phosphorus	
Coking Coal	LREEs	Scandium	

Table 9: CRMs in 2020 (Bobba, et al. 2020)

Material can be CRMs for differing reasons; they have a high economical value, they have a high supply risk, or they lack viable substitutes. In the HiFi solution there will be CRMs used in the PCBs, of which at least 12 could be recovered. (Circular Industries, n.d.)

To aid the recovery of CRMs the printed circuit boards should be easily separable from its enclosure.

Conclusion

PCBs should be separable from their enclosures

PCBs

“Plastics including polyvinyl chloride (PVC) cabling are used for printed circuit boards, connectors, plastic covers, and cables. When burnt or landfilled, these PVCs release dioxins that have harmful effects on human reproductive and immune systems.”

“[…] leaving sufficient room for later adaptation and additions in a subsequent round that are not necessarily included in the present stage […”]

“The reuse of components has been become first priority; (2) Dismantling the hazardous components is very important; and (3) It is also important to recover the highly valuable components and high-grade materials such as batteries in order to simplify the subsequent recovery of materials.”

The three quotes above all come from the Waste Electrical and Electronic Equipment (WEEE) Handbook. (Goodship, et al. 2019) They indicate the need for PCBs to be accessible and removable, the enclosures they are placed in to be ‘flexible’ and the components placed on the PCBs to be separable. The latter is hard to accomplish as an Industrial Designer, the first two can be via thoughtful design.

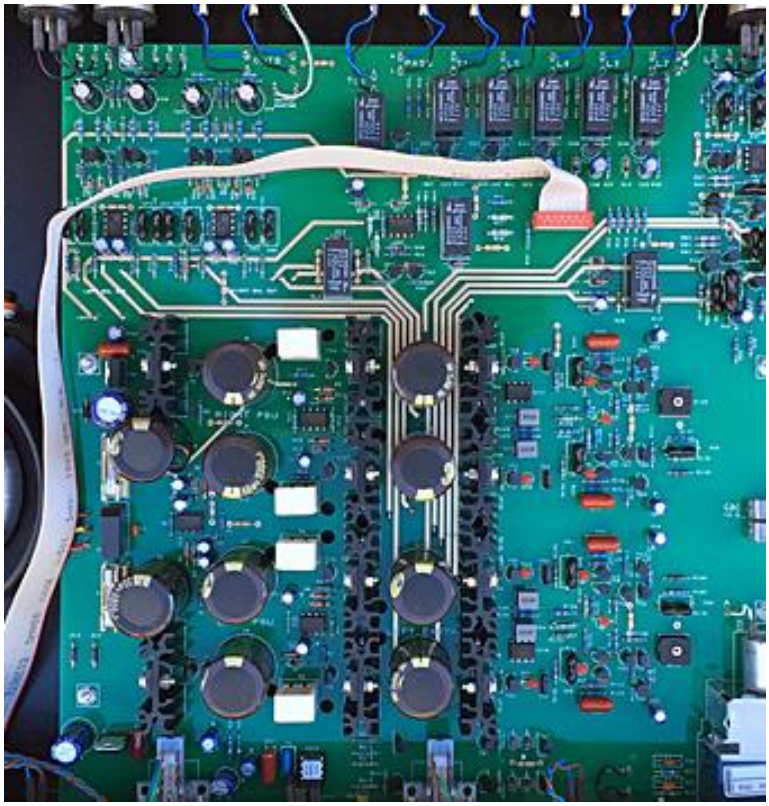


Figure 30: Gold plated PCB of a Sugden LA4

Conclusion

Cables should be detachable from the PCB // Cables are not soldered to the PCB

HiFi solution should be able to implement future developments

Transformers

Transformers are a key component in HiFi equipment, they provide the current needed by the amplifier to drive the speakers. In appendix H the three types of transformers used in HiFi equipment can be seen. The way they work is different, but they all use copper wire to step down the signal voltage.

"Primary copper production is a major activity in the mining sector. It is highly energy-intensive, ranking third in specific energy consumption (SEC) among the five major basic metals (aluminum, copper, iron, lead and zinc) and poses important environmental hazards. " (Alvarado, et al. 1999)

Figure 31: Toroidal transformers

Conclusion

For the HiFi solution to be sustainable the transformers should be easily accessible, reusable and replaceable.

Appendix G- Modular products analysis

Modular products

Modular products are widely available, in all kinds of product categories. 9 out of 10 respondents, that partook in the questionnaire, indicated they were familiar with modular products.

Modular design can be used for almost any product imaginable, but is modular design applied to all products the same way? Examples of modular products are widespread; a traditional desktop computer, a modern car or the Fairphone. To determine how modular design is applied in current designs, a selection of modular products and concepts are analysed. How are they designed and how is modularity used?

What is the definition of 'modular'?

1. Cambridge Dictionary: "consisting of separate parts that, when combined, form a complete whole" (Cambridge)

2. American Dictionary: "Made from a set of separate parts that can be joined together to form a larger object" (Cambridge)

3. Business English: "Made of several parts that can be put together in different ways" (Cambridge)

4. Merriam-Webster: "Constructed with standardized units or dimensions for flexibility and variety in use"

5. Dictionary.com: composed of standardized units or sections for easy construction or flexible arrangement.

6. Dictionary.com: *Computers*; composed of software or hardware modules that can be altered or replaced without affecting the remainder of the system.

7. Wikipedia: "modularity is the degree to which a system's components may be separated and recombined, often with the benefit of flexibility and variety in use"

8. Wikipedia: "Product systems are deemed "modular", for example, when they can be decomposed into a number of components that may be mixed and matched in a variety of configurations. The components are able to connect, interact, or exchange resources (such as energy or data) in some way, by adhering to a standardized interface. Unlike a tightly integrated product whereby each component is designed to work specifically (and often exclusively) with other particular components in a tightly coupled system, modular products are systems of components that are "loosely coupled.""

9. Collinsdictionary: "In building, modular means relating to the construction of buildings in parts called modules."

10. Collinsdictionary: "Modular means relating to the teaching of courses at college or university in units called modules."

11. Collinsdictionary: (British) "of, consisting of, or resembling a module or modulus"

12. Collinsdictionary: (US) “designating or of units of standardized size, design, construction, etc. that can be arranged or fitted together in a variety of ways”

13. Princeton’s Wordnet (definitions.net): “constructed with standardized units or dimensions allowing flexibility and variety in use”

14. Wikitionary (definitions.net):: “ Consisting of separate modules; especially where each module performs or fulfills some specified function and could be replaced by a similar module for the same function, independently of the other modules.”

15. Yourdictionary: “The definition of modular is designed with standardized units that can be fit together in a variety of ways. ”

16. Yourdictionary: “Of, relating to, or based on a module or modulus. ”

17. Yourdictionary: “ Designed with standardized units or dimensions, as for easy assembly and repair or flexible arrangement and use.”

18. Yourdictionary: “Relating to, exhibiting, or being a pattern of growth in which similar morphological units, called modules, are added repeatedly ”

19. Yourdictionary: “ Designating or of units of standardized size, design, construction, etc. that can be arranged or fitted together in a variety of ways.”

20. Yourdictionary: “Consisting of separate modules; especially where each module performs or fulfills some specified function and could be replaced by a similar module for the same function, independently of the other modules. ”

https://dictionary.cambridge.org/dictionary/english/modular

https://www.merriam-webster.com/dictionary/modular#other-words

https://www.dictionary.com/browse/modular

https://en.wikipedia.org/wiki/Modularity

https://www.collinsdictionary.com/dictionary/english/modular

https://www.definitions.net/definition/modular

https://www.yourdictionary.com/modular

Modular Products (Overview of modular product development)
“Modular products refer to products, assemblies and components that fulfill various functions through the combination of distinct building blocks (modules). “
“Increased feasibility of product/component change. Since each module interface is strictly specified, changes can be made to a module independently of other modules, provided the interfaces remain within specifications.”

Model Based Systems Engineering in construction Kit Development

The term “construction kit” is defined by KOLLER as follows: A construction kit consists of components (assemblies or parts) of identical or differing functionality and build, which can be differently combined into more complex systems with different functionality and build [31] (similar to [25, 16, 32]). In other sources a construction kit is described as a reservoir of elements [33] or as an organizing principle which contains a collection of standardized units [34]. Additionally, a construction kit provides a set of rules, which allows for the configuration of a system out of the elements [32].

Design Rules: The power of Modularity

What is modularity?

“The first is the idea of interdependence within and independence across modules.

A module is a unit whose structural elements are powerfully connected among themselves and relatively weakly connected to elements in other units. Clearly there are degrees of connection, thus there are gradations of modularity.

In other words, modules are units in a larger system that are structurally independent of one another, but work together. The system as a whole must therefore provide a framework – an architecture – that allows for both independence of structure and integration of function.

The second idea is captured by three terms: abstraction, information hiding, and interface.”

Hatch, N. W., Baldwin, C. Y., & Clark, K. B. (2001). Design Rules, Volume 1: The Power of Modularity. The Academy of Management Review, 26(1), 130. https://doi.org/10.2307/259400

Cluster 1

1. Cambridge Dictionary: “consisting of separate parts that, when combined, form a complete whole” (Cambridge)

2. American Dictionary: “Made from a set of separate parts that can be joined together to form a larger object” (Cambridge)

5. Dictionary.com: composed of standardized units or sections for easy construction or flexible arrangement.

9. Collinsdictionary: “In building, modular means relating to the construction of buildings in parts called modules.”

18. Yourdictionary: “Relating to, exhibiting, or being a pattern of growth in which similar morphological units, called modules, are added repeatedly ”

Cluster 2

3. Business English: “Made of several parts that can be put together in different ways” (Cambridge)

4. Merriam-Webster: “Constructed with standardized units or dimensions for flexibility and variety in use”

5. Dictionary.com: composed of standardized units or sections for easy construction or flexible arrangement.

12. Collinsdictionary: (US) “designating or of units of standardized size, design, construction, etc. that can be arranged or fitted together in a variety of ways”

13. Princeton’s Wordnet (definitions.net): “constructed with standardized units or dimensions allowing flexibility and variety in use”

15. Yourdictionary: “The definition of modular is designed with standardized units that can be fit together in a variety of ways. ”

17. Yourdictionary: “ Designed with standardized units or dimensions, as for easy assembly and repair or flexible arrangement and use.”

19. Yourdictionary: “ Designating or of units of standardized size, design, construction, etc. that can be arranged or fitted together in a variety of ways.”

Cluster 3

6. Dictionary.com: Computers; composed of software or hardware modules that can be altered or replaced without affecting the remainder of the system.

7. Wikipedia: “modularity is the degree to which a system's components may be separated and recombined, often with the benefit of flexibility and variety in use”

8. Wikipedia: “Product systems are deemed "modular", for example, when they can be decomposed into a number of components that may be mixed and matched in a variety of configurations. The components are able to connect, interact, or exchange resources (such as energy or data) in some way, by adhering to a standardized interface. Unlike a tightly integrated product whereby each component is designed to work specifically (and often exclusively) with other particular components in a tightly coupled system, modular products are systems of components that are "loosely coupled.””

14. Wikitionary (definitions.net):: “ Consisting of separate modules; especially where each module performs or fulfills some specified function and could be replaced by a similar module for the same function, independently of the other modules.”

20. Yourdictionary: “Consisting of separate modules; especially where each module performs or fulfills some specified function and could be replaced by a similar module for the same function, independently of the other modules. ”

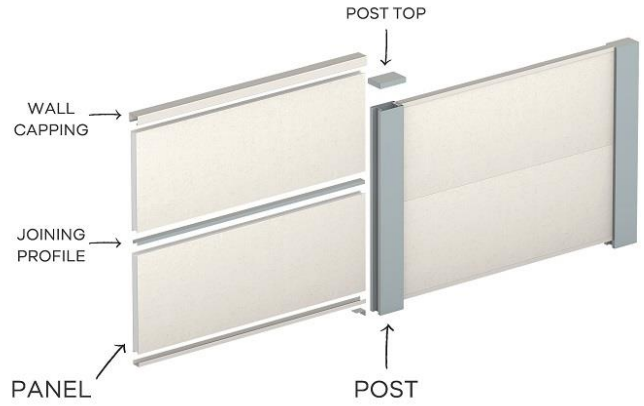
Modular products

Modular design can be used for almost any product imaginable, but is modular design applied to all products the same way? Examples of modular products are widespread; a traditional desktop computer, a modern car or the Fairphone. To determine how modular design is applied in current designs, a selection of modular products and concepts are analysed. How are they designed and how is modularity used?

Modular Fence - ModularWalls

ModularWalls is a company which delivers fencing solutions to the consumer and business market. The portfolio contains a wide variety of modular fencing systems, offering a suitable solution in almost any situation. The fence can be installed by the customers themselves, or by a third party partner.

During installation some parts are permanently locked in place, the posts are secured in concrete. The panels slide in the posts and are coupled using joining profiles, without the use of fasteners. The results in easy replacement of single panels in case of damage. The fencing systems are available with a factory finish, or can be finished by the end users themselves as desired.



Modularity

ModularWalls products lose part of their modularity after installation, it can't be dismantled and reused completely, they are "permanently" installed. The individual panels can be easily replaced if needed.

https://modularwalls.com.au/blog/what-is-a-modular-wall/

Modular boat – Lifebuoy Boat

The 'Lifebuoy Boat' concept is designed to safe human life after an emergency at sea. The concept consists of two parts, one serving as the bow and stern, the other as a middle section. Each module can hold one person, and linked together they form a complete "boat".

Modularity

One module can hold one person, minimizing the risk in case of a leak. Not only the risk is minimized in case of a leak, the associated waste is minimized as well. Secondly each trip the number of modules can be tailored to the number of people joining, minimizing space required while maximizing safety.

https://www.trendhunter.com/trends/boat-concept

Modular Camera – Leica U

The modular camera concept by Leica is made up of a set of individual modules that together form a camera. “The Leica U camera concept allows pieces to be replaced as needed but also works to help photographers utilize the exact kind of equipment that they require without having to switch cameras or devices.” (Trendhunter, 2017)

Modularity

The goal of Leica is for the camera system never to become outdated and obsolete. By placing the different functions and parts in separate modules the customer can create the camera needed for their situation. If one of the functions is outdated, it can be upgraded to the latest version, without replacing the whole camera. The Leica U remains modular throughout its usage.

https://www.trendhunter.com/trends/leica-u

Modular Glasses - NOGS

The NOGS concept is a set of parts that can be put together, by the user, to form sunglasses. Each part is available in different colours, finishes and shapes, allowing the customer to match their sunglasses to their outfit that day.

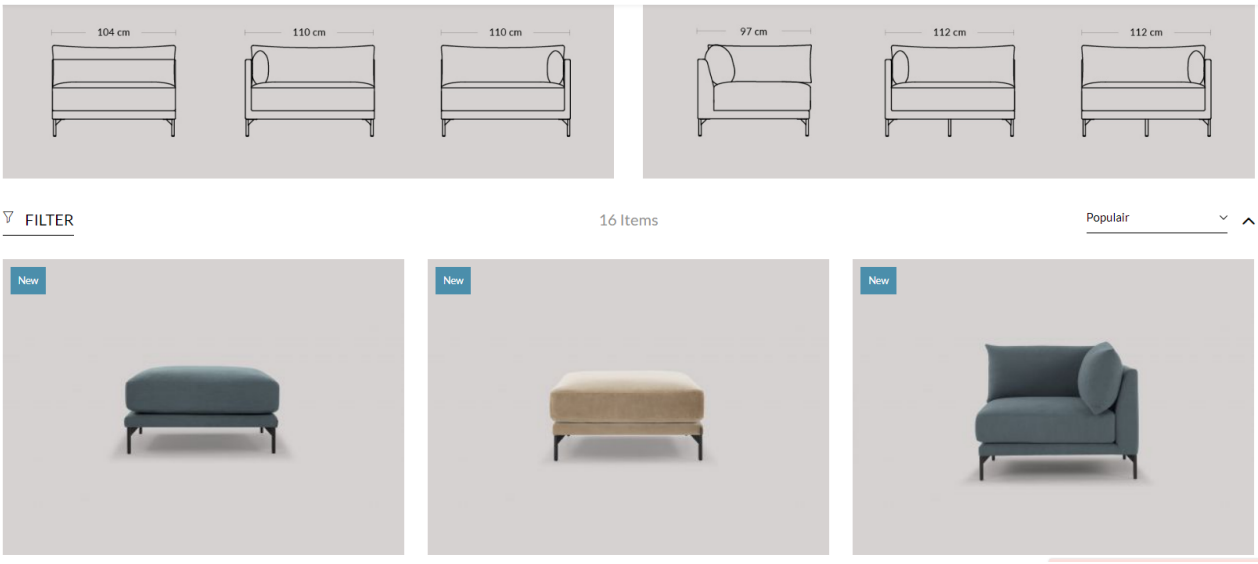
Modularity

The NOGS glasses consist of 4 parts that can be assembled, disassembled and reassembled by the user. By eliminating permanent fasteners the glasses can be reused and redesigned over and over again. The glasses are designed ass sunglasses, however an optician can make ‘normal’ clear glasses for then.

https://www.trendhunter.com/trends/nogs

Modular Sofa - SOFACOMPANY

SOFACOMPANY offers multiple variations of modular couches. Modular couches allow the user to choose the size of their couch at purchase, and the addition of extra modules after purchase. The modules are available from stock, in a selected range of colours, and can be ordered in almost any colour.



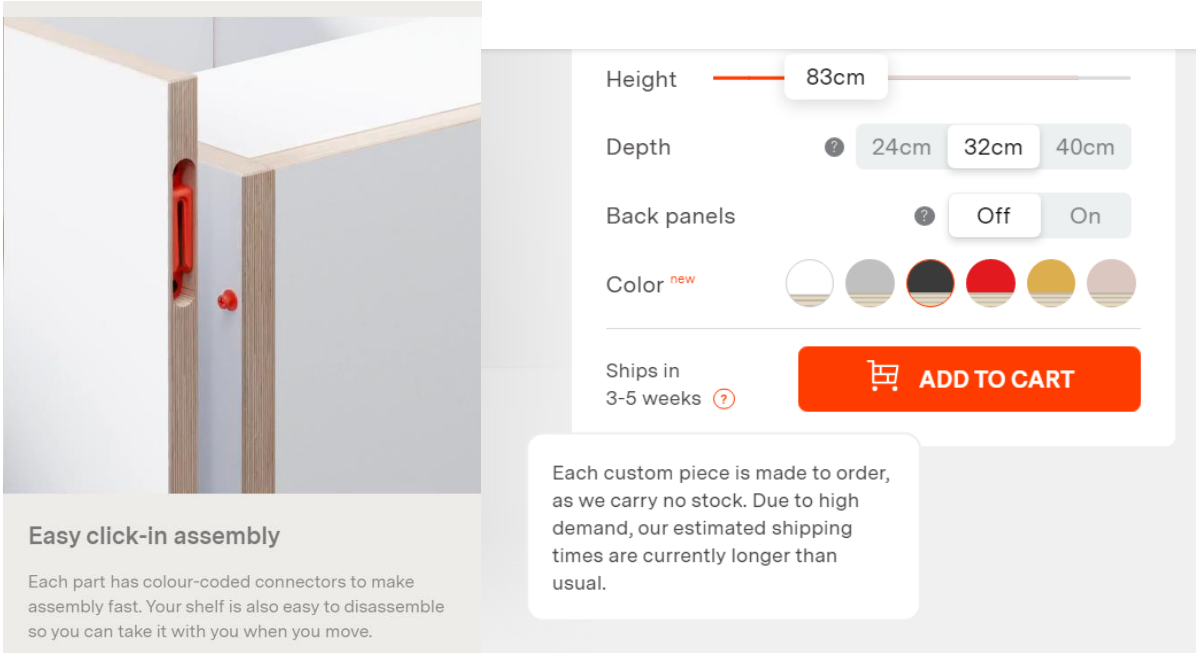
Modularity

Modular couches are designed based on two modular principles. The first has designated corner pieces and middle sections. The second allows arm- and back- rests to be added to the base, making a corner from a middle pieces. The latter gives the user greater freedom after purchase, since a piece of the couch can also be turned into a chair for example.

https://nl.sofacompany.com/designbank/modulaire-bank?product_list_limit=all

Modular storage system - Tylko

Tylko offers a range of modular storage solutions for the consumer market. Tylko offers preconfigured cabinets, or allows the user to design it themselves, using a online tool. They have four material options, with a wide variety of finishes. They produce the cabinets after an order is placed, resulting in long delivery times, but no sitting stock.



Modularity

Tylko offers an online configuration tool to create precisely the storage solution needed by the customer. The different material types and colour finishes offer them a selection too choose from at purchase, but not afterwards.

https://tylko.com/shelf/318173/?cv=1

Modular Headphones – Gerrard street

Gerrard Street is a Dutch company which offers three different types of modular headphones. There are two wireless versions, of which one offers better sound quality, and a wired one. The Headphones can be bought or leased, but either way they come with free repairs. If a part gets broken, or worn out, the customer can request and new one, and ship the old one back for refurbishment.

Modularity

The headphones from Gerrard Street use a modular design purely for it's sustainability benefits. By it's modular design it is very easy to repair for the customer, by just replacing the broken part. The user does not get to configure their perfect headphone. Upgrading is possible, if the headphones are leased, by changing the subscription using the users online account. They will be send a new, pair, after which they can ship their current ones back.

https://gerrardstreet.nl/

Modular Phone - Google Ara

Google Ara (Left), or Project Phonebloks (Right), is a modular phone concept. The concept was designed for 6 billion users, 1 billion smartphone users, and 5 billion featurephone users. By combining different modules the user could select the functions and features they wished and required. The concept never made it to reality.

Modularity

Project Ara was a completely modular phone. It started with a starter kit with a; with frame, display battery, low end CPU, and Wi-Fi module. It was meant to be open source, without a fee for manufacturers to participate. Via software it would be locked to original modules, however this could be turned off by the user. Project Ara was meant to be available online and offline.

https://en.wikipedia.org/wiki/Project_Ara

Modular Kitchen - Ikea Knoxhult

Ikea has four different modular kitchen product lines, of which The Knoxhult is one. Within each product line there are a range of different “modules” available, which can be combined to get all the wished functions, and fill the available space.

Modularity

Via an online tool the Knoxhult, or one of the other product lines of Ikea, can be configured and “tested” in the designated location. The kitchens are modular before purchase, with regards to size and dimension, and can be personalized and adjusted with additional accessories. The Knoxhult product line is a total package, from cabinet to lighting fixtures to door handles.

Modular Amplifier – Cello Audio Suite

The Audio Suite is a modular amplifier designed by Cello. The Audio Suite is a high performing amplifier, with modules available at different price points and specifications. The frame and modules were both designed and produced by Cello. Nowadays Cello as a company still exists, but does not produce HiFi equipment anymore.

Modularity

The Audio Suite offers modules in two categories, Basic and Premium, both input and output modules. Basic and Premium input modules could freely be mixed, allowing the user to focus on specific functions. Basic and Premium output modules could not be mixed. The goal of Cello was to allow user to add and upgrade functions as desired.

Desktop PC

The Desktop Personal Computer or PC is a prime example of modularity and standardization. The PC is not owned by one manufacturer, but standardized. This means that manufacturers can design and make their products, following certain rules, and it will work.

Modularity

The PC is a prime example of modularity and standardization. Products of multiple manufacturers can be combined in one enclosure and it will work, as long as a few rules are followed. The modular design of Personal Computers gives the user the ability to configure the PC exactly to their needs and wishes. During use the PC can also be upgraded, or repaired, by changing specific parts without touching the rest.

Windscreen wipers

Windscreen wipers are an example of standardization and modularity. A user can select windscreen wipers from a wide variety of brands, that will all fit his car, as long as the connection mechanism is correct. There are a few different methods to fixate the windscreen wipers.

Modularity

Windscreen wipers use modularity to easily replace the part that wears over time, the rubber strip. It would be possible to only replace the rubbers, however, changing the rubber with the plastic armature is easier for the end user.

Bicycle

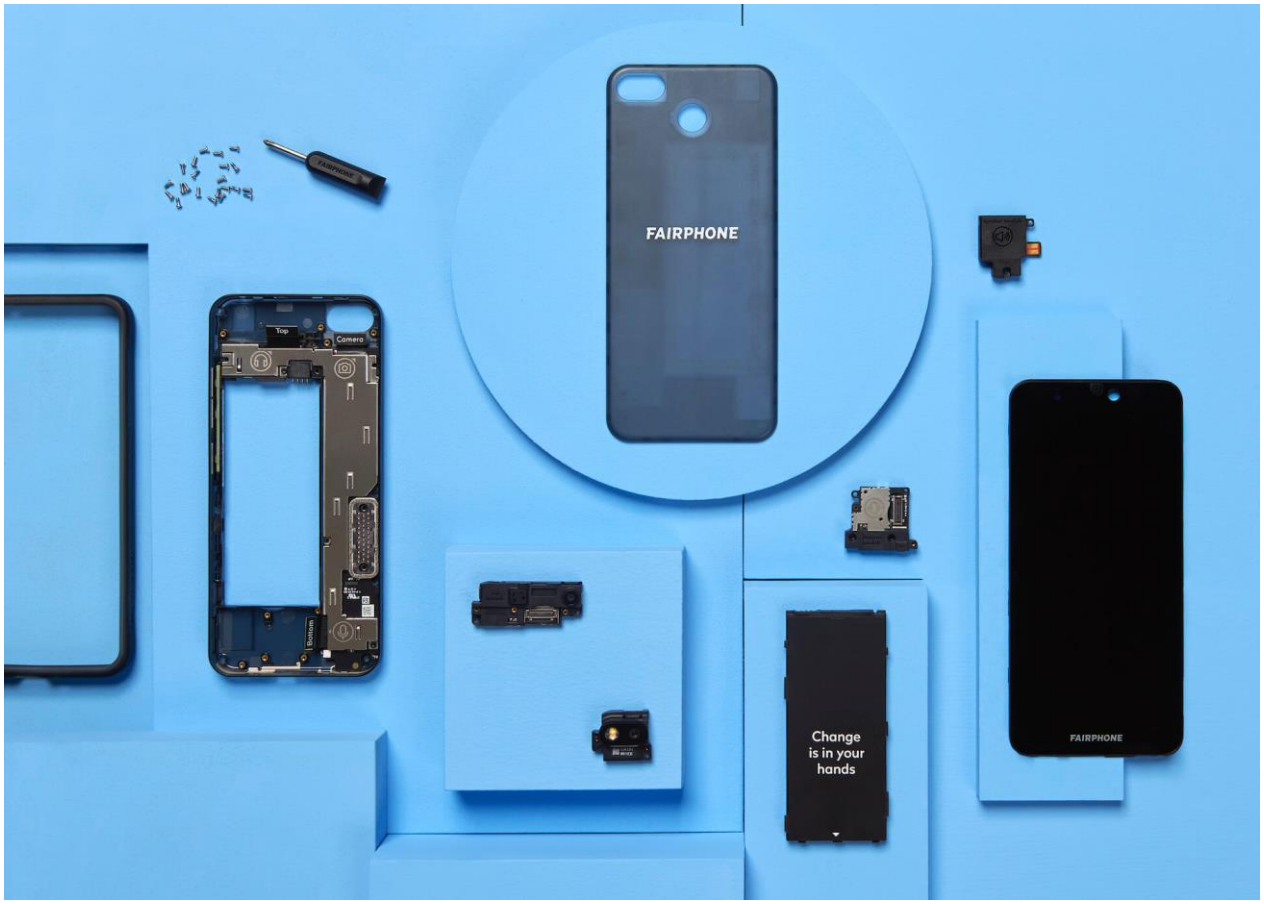
Bicycles come in all shapes and sizes, designed for specific use cases, or for all-round usage. Nevertheless, almost all bikes are (partly) modular, and standardized.

Modularity

Bicycles are mainly modular to extend their life cycle. Many parts are also standardized, for example the rims and tyres, there are multiple sizes available, but an 26inch wheel bought in Afrika will fit a Dutch bike. All parts are available at different price levels, and levels of performance, and can be selected by the user. In most cases bikes will not be upgraded, but maintained.

Modular Phone - Fairphone

Fairphone is a Dutch company that currently has two modular phones on the market, the Fairphone 3 and 3+. Next to selling their current phones, they also offer replacement parts for their current and previous phone.



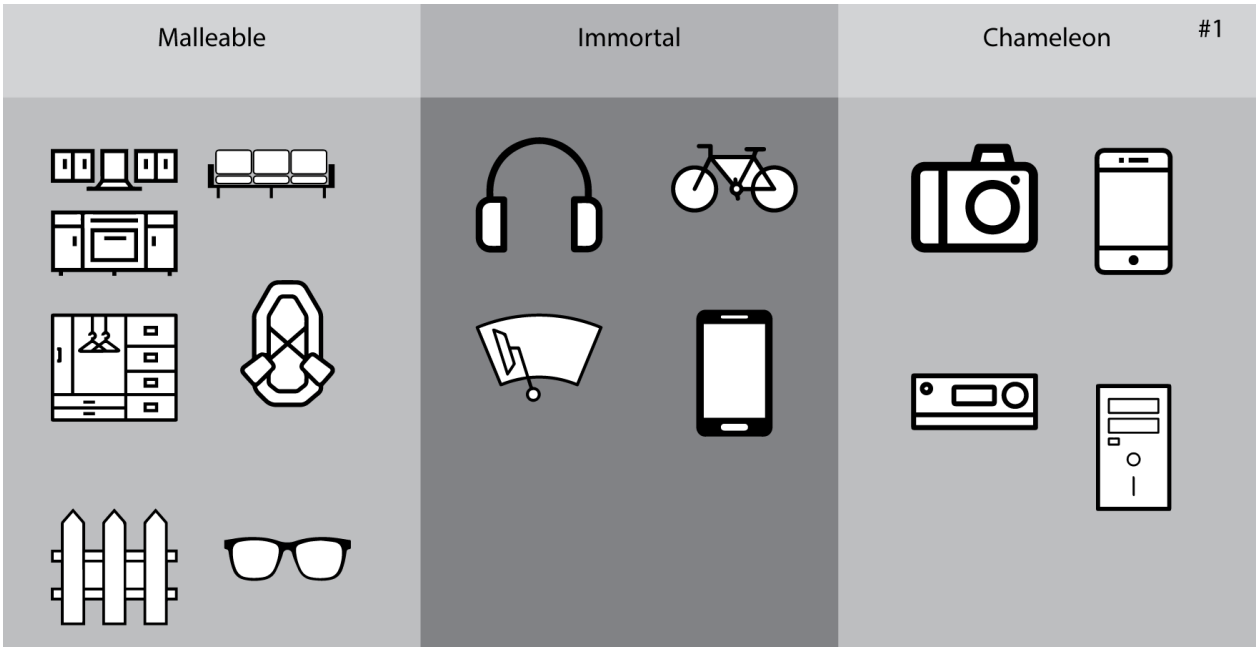
Modularity

Fairphone has adopted a modular design to elongate the technical and functional lifetime of their products. Different functions are enclosed in their own compartment, but are unlike with Project Ara not meant to be upgraded, but to be easily replaced in case of a defect. Replacing the modules can be done by the owners themselves. Although the modular design is adopted to improve repairability and elongate the product life, some modules now also have an upgraded version.

Clusters

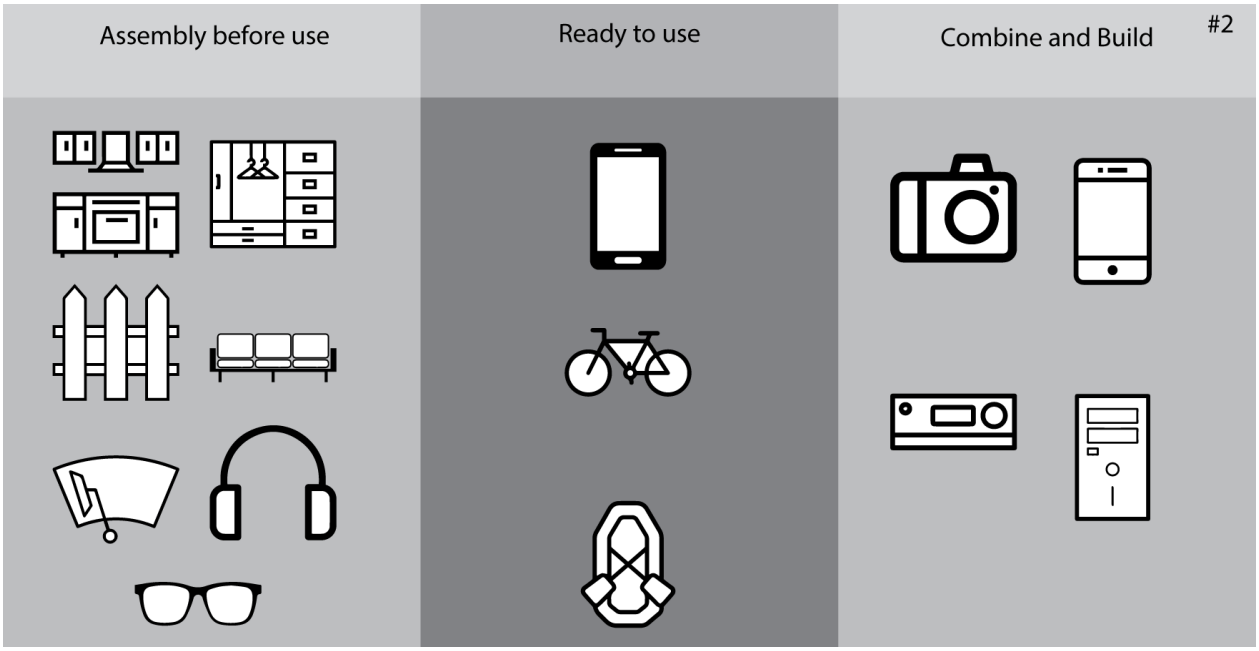
Cluster 1

When are the benefits of modularity utilized`



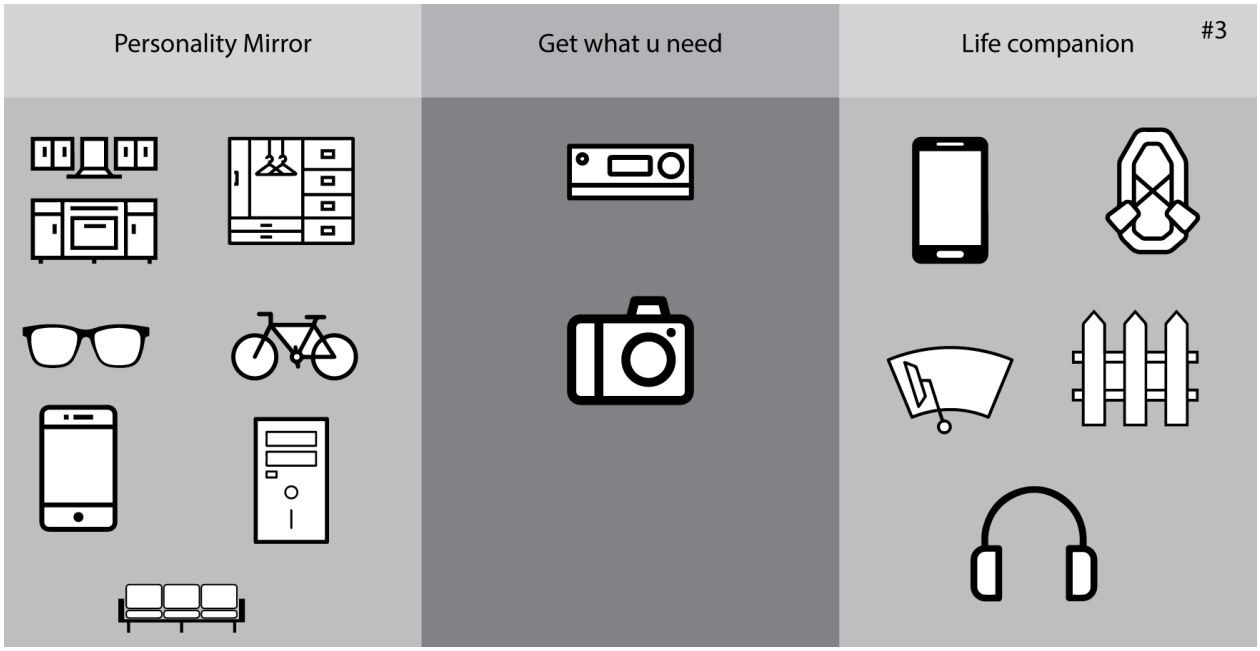
Cluster 2

Where is the product put together

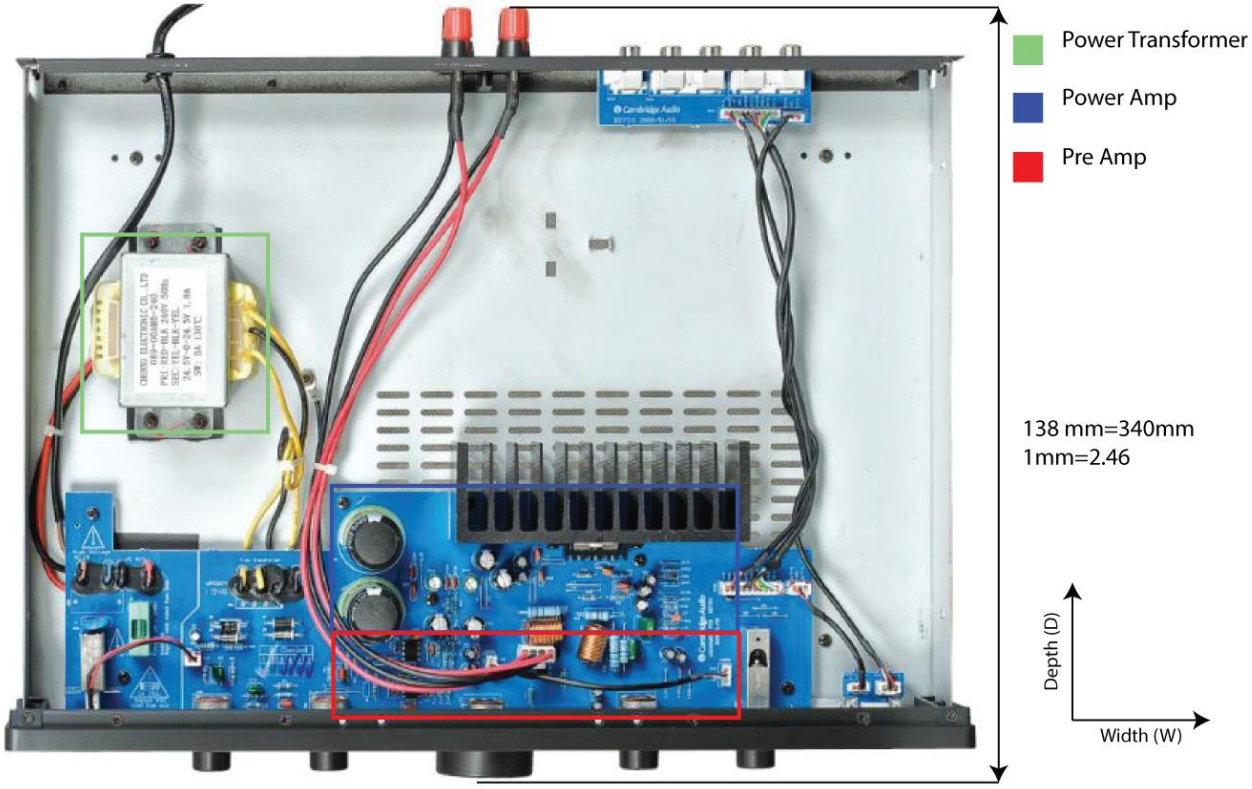


Cluster 3

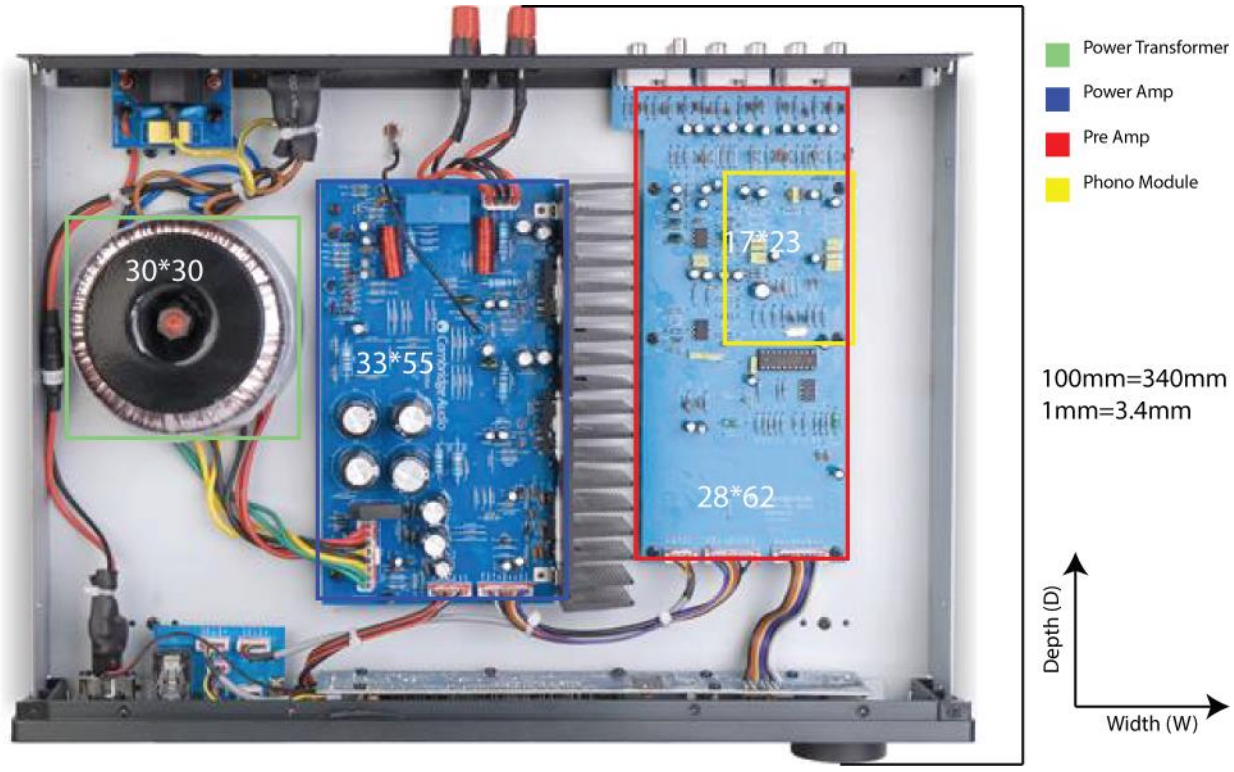
What are the benefits of the modular design fort he user?



Appendix H – Function Dimensions Analysis

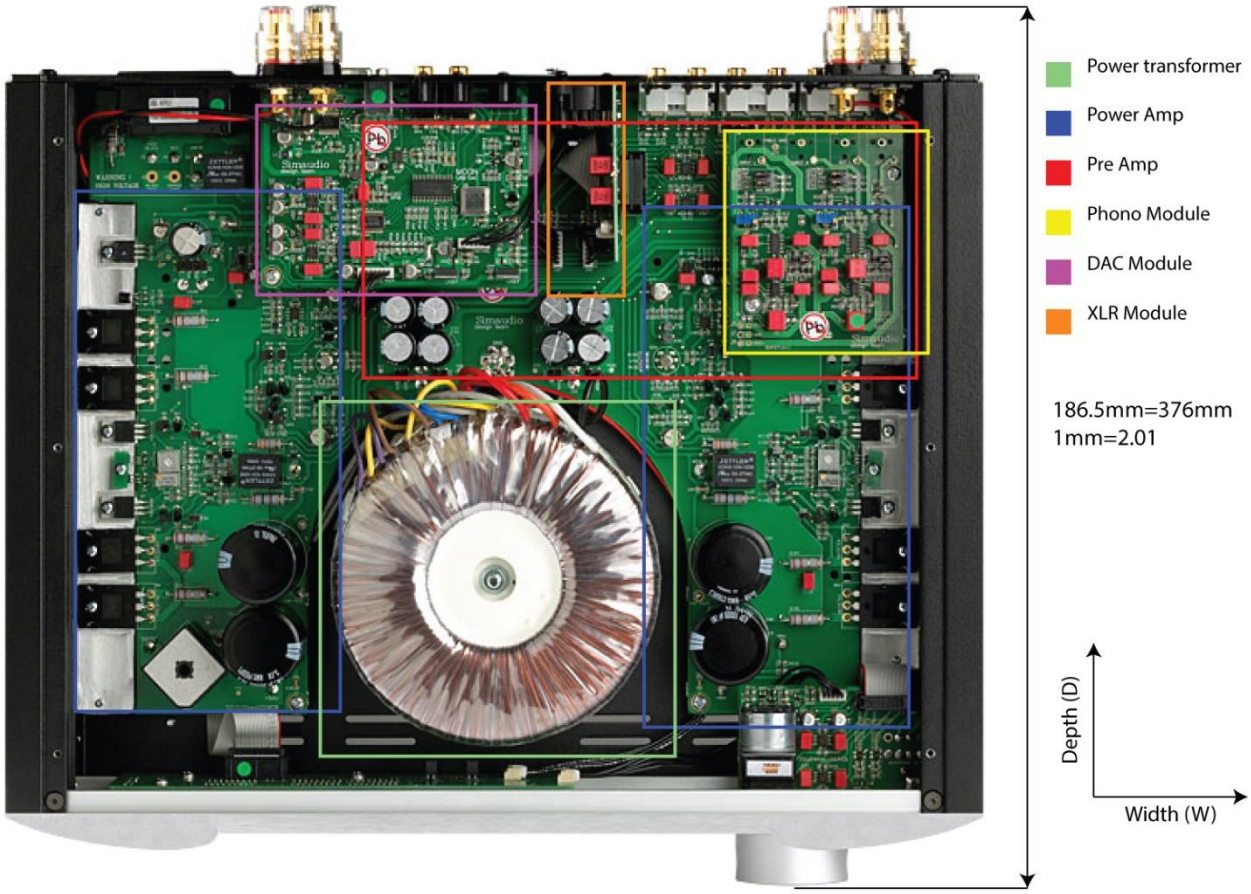


Top view	W	D		W (mm)	D (mm)	H (mm)
Cambridge AM5		Schaal	2,46			83
PS: Linear	33	35		81,18	86,1	
Pre amplifier	72	15		177,12	36,9	
PA: Class AB	72	26		177,12	63,96	

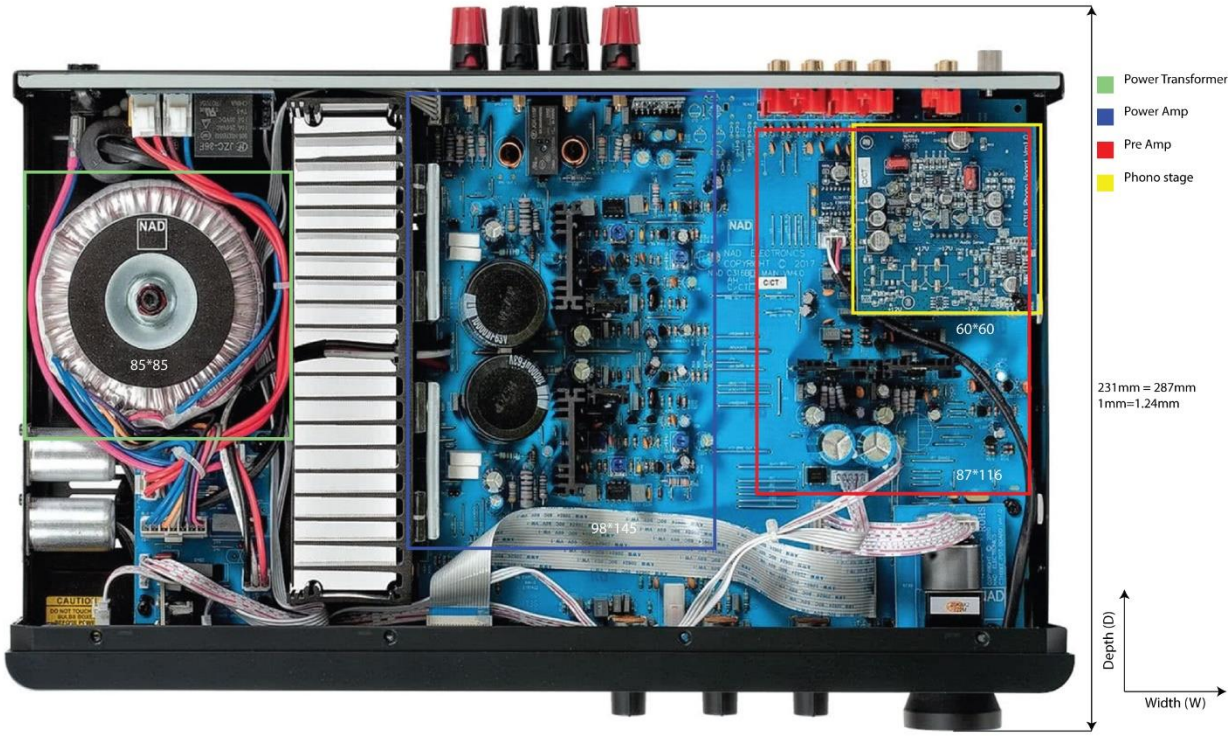


Top view	W	D		W (mm)	D (mm)	H (mm)
Cambridge AM10		Schaal	3,4			83
PS: Linear	30	30		102	102	
Pre amplifier	28	62		95,2	210,8	
PA: Class AB	33	55		112,2	187	
Phono stage	17	23		57,8	78,2	

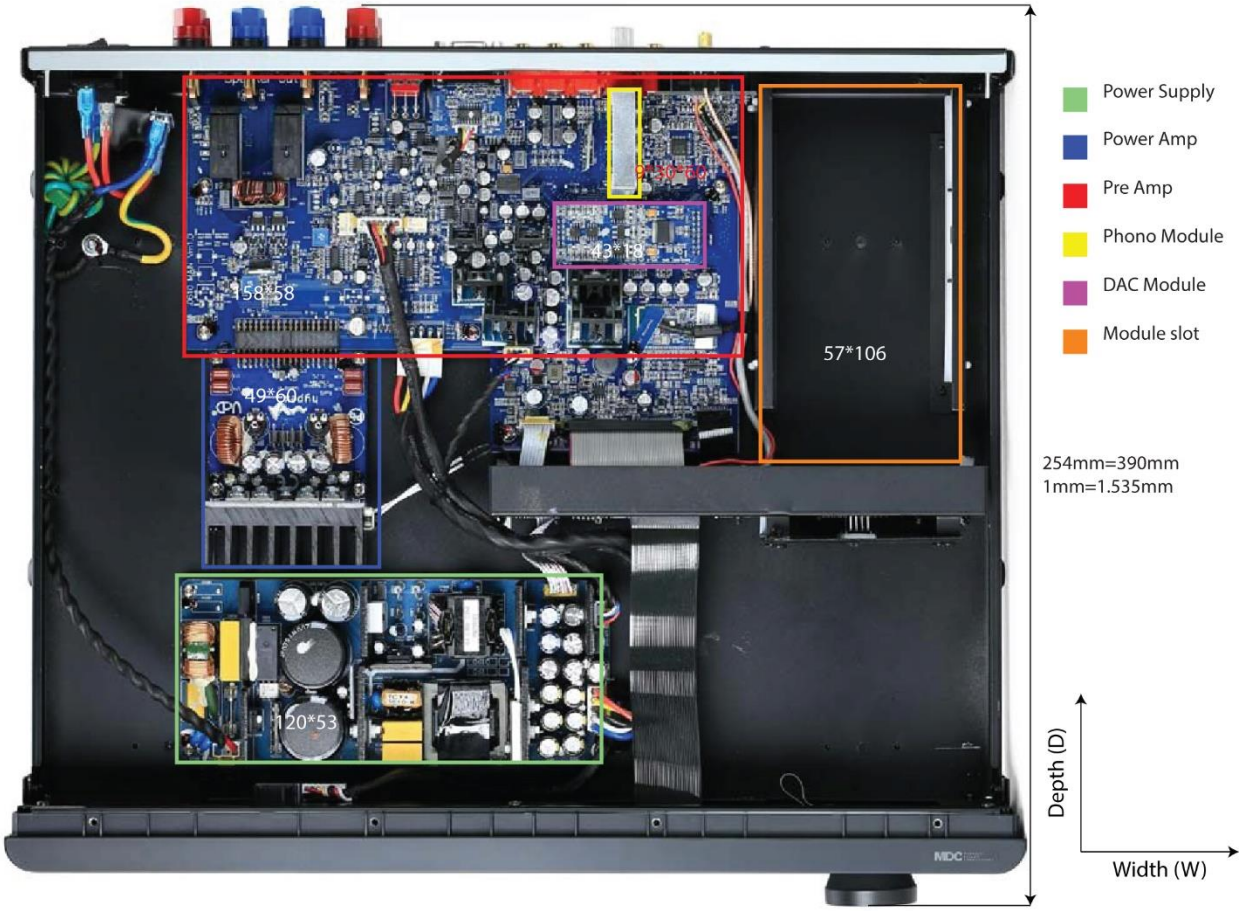
Top view	W	D		W (mm)	D (mm)	H (mm)
Moon ACE		Schaal	1,01			89
Power Transformer	117	117		118,17	118,17	
Pre amplifier	192	73		193,92	73,73	
PA: Class AB	254	122		256,54	123,22	
Phono stage	56	90		56,56	90,9	
Streamer	109	68		110,09	68,68	
DAC	115	118		116,15	119,18	



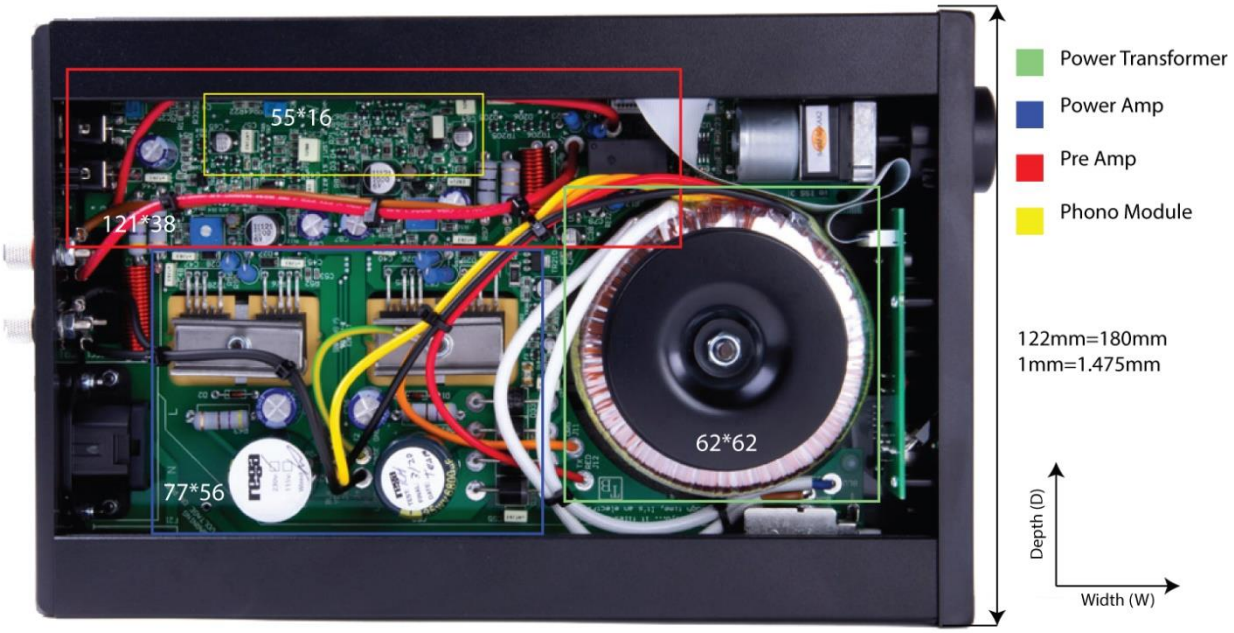
Top view	W	D		W (mm)	D (mm)	H (mm)
moon 340i		Schaal	2,01			89
PS: Linear	75	75		150,75	150,75	
Pre amplifier	117	54		235,17	108,54	
PA: Class AB (2x)	56	110		112,56	221,1	
Phono stage	43	47		86,43	94,47	
XLR	26	45		52,26	90,45	
DAC	59	40		118,59	80,4	



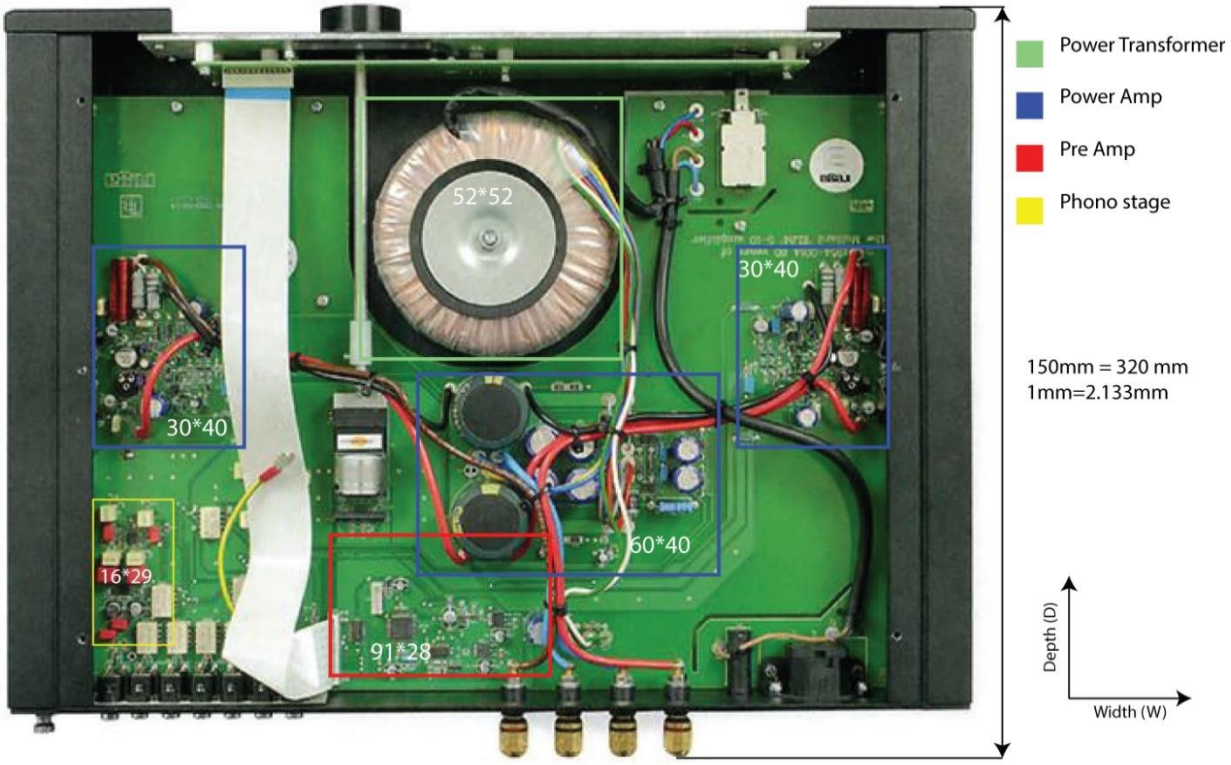
Top view	W	D		W (mm)	D (mm)	H (mm)
Nad 316Bee		Schaal	1,24			80
PS: Linear	85	85		105	105,4	
Pre amplifier	87	116		107,88	143,84	
PA: Class AB	98	145		121,52	179,8	
Phono stage	60	60		74,4	74,4	



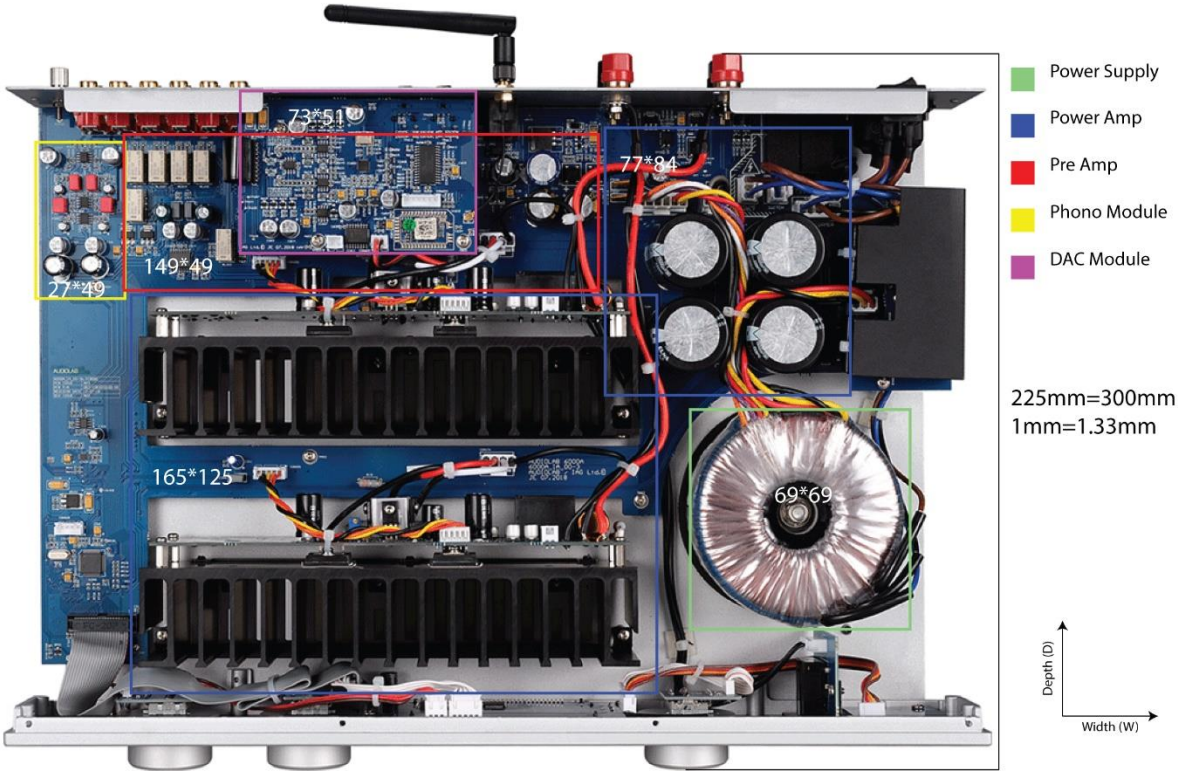
Top view	W	D		W (mm)	D (mm)	H (mm)
NAD C368		Schaal	1,535			89
SMPS	120	53		184,2	81,355	
Pre amplifier	158	58		242,53	89,03	
PA: Class D	49	60		75,215	92,1	
Phono stage	30	60		46,05	92,1	
DAC	43	18		66,005	27,63	
Module slot	57	106		87,495	162,71	



Top view	W	D		W (mm)	D (mm)	H (mm)
Rega IO		Schaal	1,475			68
PS: Linear	62	62		91,45	91,45	
Pre amplifier	121	38		178,475	56,05	
PA: Class AB	77	56		113,575	82,6	
Phono stage	55	16		81,125	23,6	



Top view	W	D		W (mm)	D (mm)	H (mm)
Rega Elex R		Schaal	2,285			80
PS: Linear	52	52		118,82	118,82	
Pre amplifier	91	28		207,935	63,98	
PA: Class AB (2x)	30	40		68,55	91,4	
	60	40		137,1	91,4	
Phono stage	16	29		36,56	66,265	



Top view	W	D		W (mm)	D (mm)	H (mm)
Audiolab 6000a		Schaal	1,33			80
PS: Linear	69	69		91,77	91,77	
Pre amplifier	149	49		198,17	65,17	
PA: Class AB	165	125		219,45	166,25	
	77	84		102,41	111,72	
Phono stage	27	49		35,91	65,17	
DAC	73	51		97,09	67,83	

Pre Amplifier			Surface area: CM2	Square root of surface area
Nad 316Bee	108	144	155	13
Rega IO	178	56	100	10
Rega Elex R	208	64	133	12
moon 340i	235	109	255	16
Audiolab 6000a	198	65	129	12
Cambridge AM5	177	37	65	9
Cambridge AM10	95	211	201	15
Moon ACE	194	74	143	12
NAD C368	243	89	216	15

Class AB amplifier			Surface area: CM2	Square root of surface area
Nad 316Bee	122	180	218	15
Rega IO	114	83	94	10
Audiolab 6000a	219	166	365	20
Audiolab 6000a	102	112	114	11
Cambridge AM8	177	64	113	11
Cambridge AM13	112	187	210	15
Moon ACE	257	123	316	18
Rega Elex R	69	91	63	8
Rega Elex R	137	91	125	12
moon 340i	113	221	249	16

Phono stage			Surface area: CM2	Square root of surface area	Type
Nad 316Bee	74	74	55	8	MM
Rega IO	81	24	19	5	MM
Rega Elex R	37	66	24	5	MM
moon 340i	86	94	82	10	MM/MC
Audiolab 6000a	36	65	23	5	MM
Cambridge AM10	58	78	45	7	MM
Moon ACE	57	91	51	8	MM
NAD C368	46	92	42	7	MM

Power Transformer	W	D	Surface area: CM2	Square root of surface area
Nad 316Bee	105	105	111	11
Rega IO	91	91	84	10
Rega Elex R	119	119	141	12
moon 340i	151	151	227	16
Audiolab 6000a	92	92	84	10
Cambridge AM10	102	102	104	11
Moon ACE	118	118	140	12

DAC			Surface area: CM2	Square root of surface area
moon 340i	119	80	95	10
Audiolab 6000a	97	68	66	9
Moon ACE	116	119	138	12
NAD C368	66	28	18	5

Module slot			Surface area: CM2	Square root of surface area
NAD C368	87	163	142	12
PA: Class D				
NAD C368	75	92	69	9
SMPS				
NAD C368	184,2	81,355	150	13
Streamer				
Moon ACE	110,09	68,68	76	9
XLR				
moon 340i	52,26	90,45	47	7
Blok transformer				
Cambridge AM5	81	86	70	9

Amplifier	Width	Depth	Surface area (A): CM2	Square root of A	
Rega IO	81	24	19	5	Phono stage
Rega Elex R	37	66	24	5	Phono stage
Audiolab 6000a	36	65	23	5	Phono stage
NAD C373	66	28	18	5	Dac
Cambridge AM14	58	78	45	7	Phono stage
NAD C372	46	92	42	7	Phono stage
moon 340i	52,26	90,45	47	7	XLR
Rega Elex R	69	91	63	8	Class AB amplifier
Nad 316Bee	74	74	55	8	Phono stage
Moon ACE	57	91	51	8	Phono stage
Cambridge AM7	177	37	65	9	Pre Amplifier
Cambridge AM5	81	86	70	9	Blok transformer
Audiolab 6000a	97	68	66	9	Dac
NAD C371	75	92	69	9	PA: Class D
Moon ACE	110,09	68,68	76	9	Streamer
Rega IO	178	56	100	10	Pre Amplifier
Rega IO	114	83	94	10	Class AB amplifier
moon 340i	86	94	82	10	Phono stage
Rega IO	91	91	84	10	Power Transformer
Audiolab 6000a	92	92	84	10	Power Transformer
moon 340i	119	80	95	10	Dac
Audiolab 6000a	102	112	114	11	Class AB amplifier
Cambridge AM8	177	64	113	11	Class AB amplifier
Nad 316Bee	105	105	111	11	Power Transformer
Cambridge AM11	102	102	104	11	Power Transformer
Rega Elex R	208	64	133	12	Pre Amplifier
Audiolab 6000a	198	65	129	12	Pre Amplifier
Moon ACE	194	74	143	12	Pre Amplifier
Rega Elex R (2x)	137	91	125	12	Class AB amplifier
Rega Elex R	119	119	141	12	Power Transformer
Moon ACE	118	118	140	12	Power Transformer
Moon ACE	116	119	138	12	Dac
NAD C374	87	163	142	12	Module slot
Nad 316Bee	108	144	155	13	Pre Amplifier
NAD C369	184,2	81,355	150	13	SMPS
Cambridge AM12	95	211	201	15	Pre Amplifier
NAD C370	243	89	216	15	Pre amplifier
Nad 316Bee	122	180	218	15	Class AB amplifier
Cambridge AM13	112	187	210	15	Class AB amplifier
moon 340i	235	109	255	16	Pre Amplifier
moon 340i (2x)	113	221	249	16	Class AB amplifier

moon 340i	151	151	227	16	Power Transformer
Moon ACE	257	123	316	18	Class AB amplifier
Audiolab 6000a	219	166	365	20	Class AB amplifier

REGA

REGA						
Model	IO	BRIO	Elex	Elecit	AETHOS	OSIRIS
Power output (RMS, 2ch, 8ohm)	30	50	72,5	105	125	160
Power Consumption (230V)	135	195	250	375	415	560
Weight (g)	2900	5100	10800	13000	17500	25600
Dimensions (W*D*H) (mm)	180x290x68	216x345x78	430x320x80	432x325x82	433x360x95	434x350x122
Transformer diameter	90	95	120	130	150	2x116
Price € (Netherlands, 9-11-2020)	459	799	1299	2299	3799	8499

Functions						
Model	IO	BRIO	Elex	Elecit	AETHOS	OSIRIS
Phono	YES	YES	YES	YES	NO	NO
Headphone	YES	YES	NO	NO	YES	NO

Connections						
Model	IO	BRIO	Elex	Elecit	AETHOS	OSIRIS
Line Level	2	4	4	4	5	4
Record Out	NO	YES	YES	YES	YES	YES
Pre Out	NO	NO	YES	YES	YES	NO
Record Input	NO	NO	NO	YES	YES	YES
Direct Input	NO	NO	NO	YES	YES	YES
Balanced Input	NO	NO	NO	NO	NO	YES

Appendix F – Field research at Studio 107 with Niek the technician

Audion – Silver Night 300B (Tube amplifier)

- Reassembling products is time consuming if a clear view on top and bottom is required at the same time.
- Tube sockets have no markings on them, but tubes have 2 different diameter pins, four in total. Incorrect placement of tubes can damage the tube sockets.

300B tube socket || Square black back cover took minutes to reassemble correctly

- **Assembling and disassembling should only require a clear view on side of the HiFi solution // Assembling and disassembling can be done without a clear view**
- **Crucial parts placement should be guided by clear use cues // parts cannot be placed incorrectly**

Sugden LA4 (preamplifier)

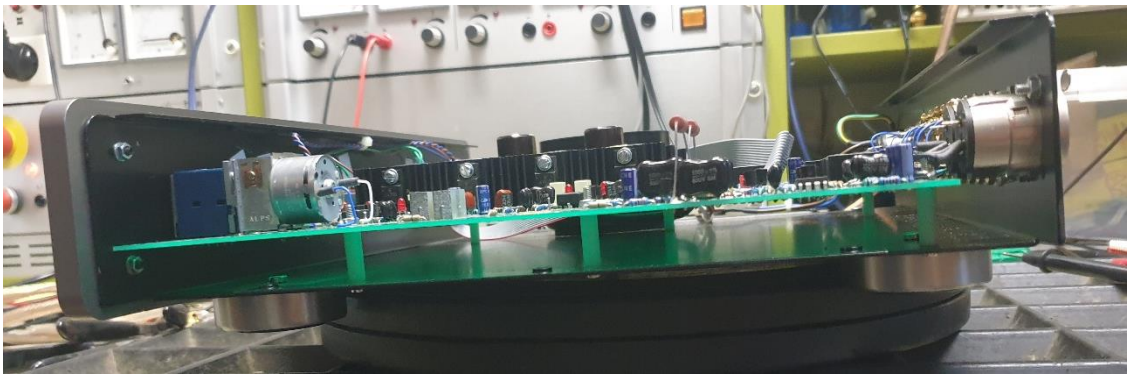
Complaint: Difference in sound levels left and right.
Fix: replace blue alps potentiometer.

Bottom enclosure made from folded sheet metal, folds at front and back. disassembly would have been quicker if folds would have been on the side. Multitude of surface mounted PCB components and hardwired terminal connections had to be removed for clean disassembly. “Solution” was to bend the PCB, just enough room for wires to stay attached.

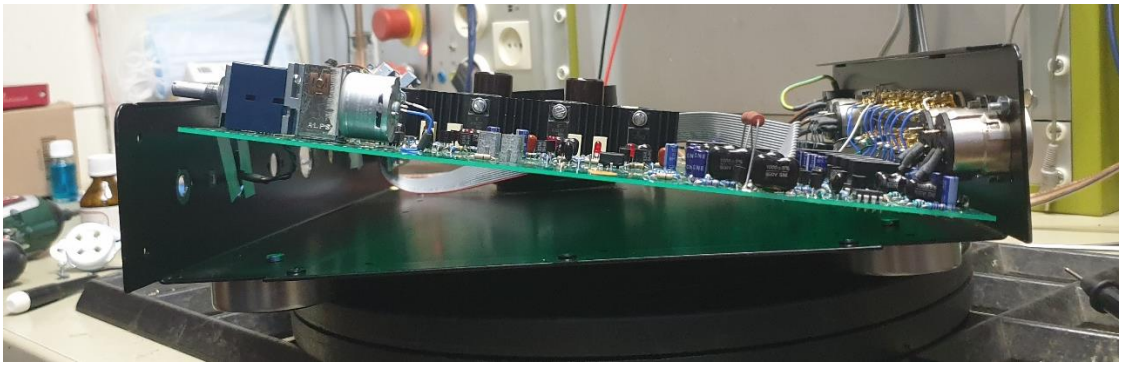
PCB removal should be as easy as possible // PCB removal requires only “household” tools

Reassembly of the PCB to the enclosure difficult due to usage of loose spacers, positioning is crucial in a limited space. Risk of damaging the PCB. Are alternatives available, bit more expensive but much quicker to assemble and disassemble (low volume, but expensive brand) (Hex Stand off)

Dissasembling should result in a minimal number of loose fastners, fixings, nuts and bolts // Disassembly results in no loose fastners, fixings, nuts and bolts.

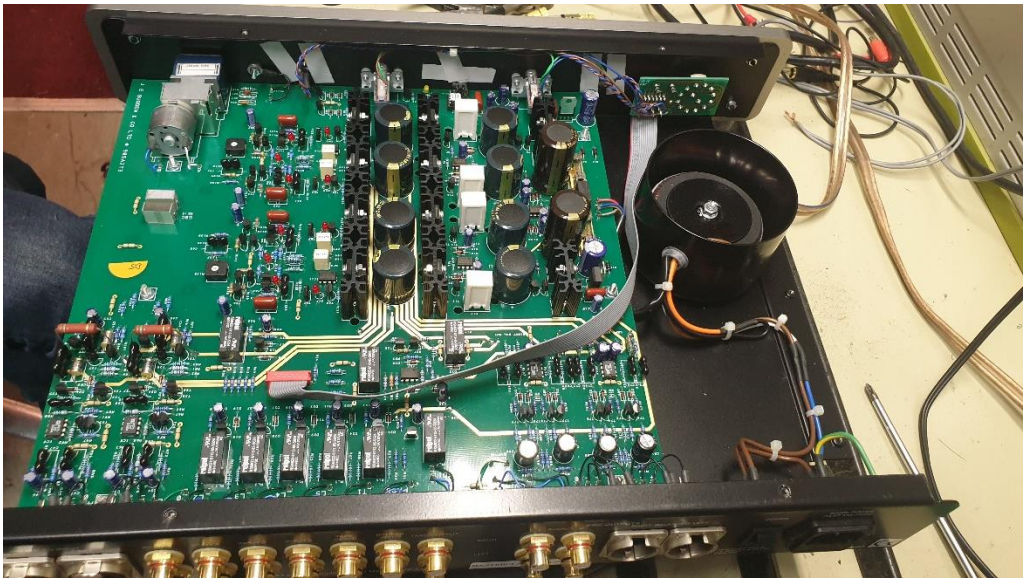


PCB is obstructed on the front and back, multitude of connections would have to undone. Nylon standoffs visible underneath the PCB, some are even two smaller pieces.



Parts fixated in place using tape, not reusable after disassembly. Visible on the left in picture above.

The use of one time fasteners should be minimized // No one time fasteners are used.



Gold plated PCB traces. Magnetic shielding visible on the right.

There are two different diameters for blue alps potentiometers (volume control) 6.0mm is the European standard, 6.3mm is the American standard. European potentiometer was fitted, but American ordered, instead of ordering new ones the hole is enlarged using a drill.

The use of readily available replacement parts should be maximized // Only readily available replacement parts should be used.

Reassembly takes unnecessary time, Hex standoff reduces it to seconds instead of the current 10-15 minutes.

Assembly time should be minimized

Metal magnetic shielding around toroidal transformer.

Electromagnetic interference should be minimized // Electromagnetic interference is prevented

Short cable length between input connectors and PCB results in a loose soldering connection after disassembly, able to resolder

The amount of soldering required to disassemble should be minimized// Disassembly requires no soldering

Sugden A21 (Integrated amplifier)

Complaint: No sound from one of the channels.
Defect: Rectifier of the right channel is blown.
Fix: Rectifier replacement.

High current at low voltage, short somewhere. Rectifier defect.

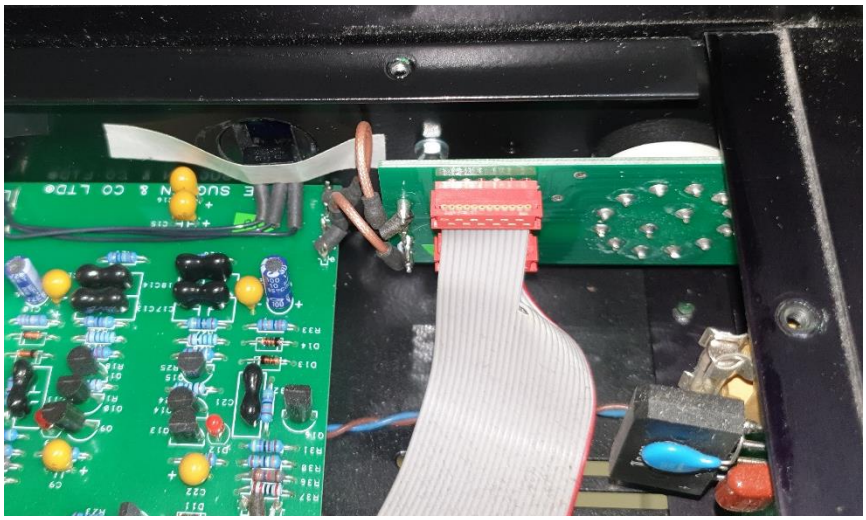
Rectifiers should be accessible // Rectifiers are all in one location.

Front panel has to be removed to disassemble to get to the internals of the amplifier.

Disassembly steps to get to crucial parts should be minimized // Crucial parts are assessable without disassembly

Fastening screw for front plate hidden behind the input control print, has to be disassembled as well.

Fasteners, fixings, nuts and bolts should be accessible // Fasteners, fixings, nuts and bolts are accessible without removal of other parts

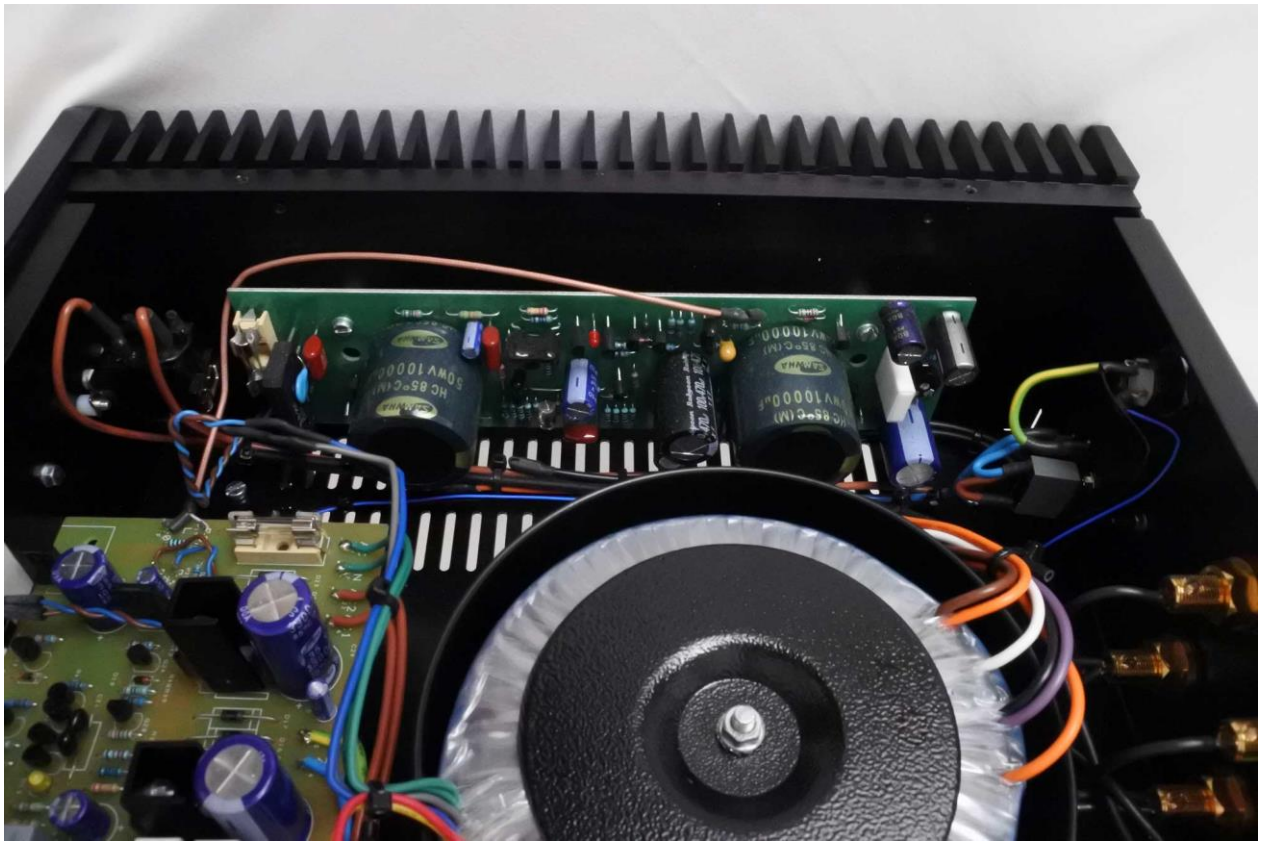


Bottom enclosure made from folded sheet metal, folds at front and back.

Signal is carried through a flat ribbon cable (RS-Online, n.d.)

Power transistors are mounted to the aluminium exterior, through the PCB, difficult to see if assembly is correct.

Correct placement of the power transistors should be inspectable // Placement of rectifiers cannot be incorrect.



Rectifier does not wear, but can blow at once. One or both channels down.

Rectifier replacement should possible // Rectifier replacement is as easy as possible

Mica plates used between transistors and Aluminium exterior, does not conduct electricity, does conduct heat.

“Impossible” to check whether mica plates are positioned correctly. After assembly still a short, mica plate not in right position after reassembly.

The risk of a short between a power transistor and their heatsink should be minimized // A short between a power transistor and their heatsink is not possible.

Heatsink fins are horizontal, should be vertical for optimal heat dissipation via convection

Heat dissipation should be sufficient // Heat dissipation is optimal.

Arcam – FMJ A32 (integrated amplifier)

Complaint: selection control not functioning correctly
Defect: grease, to ease rotation, got on the pulse generator
Fix: Disassembly the pulse generator and clean it

Sheet metal folded enclosure, folds on the sides.

Encoder, to select the inputs, generates pulses, lubricated with grease, grease got on encoder, not all pulses picked up, missed pulses.

Moving parts should be accessible // Moving parts are accessible a minimum number of steps.

The number of moving parts should be minimized // No moving parts are used

Phono module build in, separate PCB.

Fatman – Itube (integrated tube amplifier)

Glass fuse blown, wires soldered to the glass fuse, instead of glass fuse placed in a fuse holder. Difficult or impossible for users to replace themselves. (happened after changing the tubes)

Glass fuses should be in a fuse holder // The fuseholder is easy to access.

What are known weakpoints in HiFi electronics?

- Poteniometers, dust wear
- Powersupply Elco's wear due to heat.

Reduction of Elco's lifetime by heat should be minimized // Reduction of Elco's lifetime by heat is not possible.

- Speaker relay get "stuck", signal is not send through to the speaker anymore

Speaker relays should be accessible // Speaker relays are accessible in a minimum number of steps.

- Loose solder connections due to heat and associated expanding and shrinkage.

Internal temperatures should be minimized // Internal temperatures are as low as possible

Other

Solder has to be free of lead, EU regulations, less wear resistant, get loose sooner.

- Even lead-free solder elements are coproduced with lead. WEEE handbook 1.2.1

The usage of soldering is minimized // No soldering is required

Broken standby power supplies are a common defect of modern products. These power supplies are always on for the amplifier to be able to react to a remote control. The standby power supply, uses very little energy and turns on the main power supply. The power consumption of the standby power supply is 0.5w

If used the stand-by power supply should be accessible // The stand-by power supply is accessible in a minimum number of steps.

Repairs done base on specialised knowledge, not following manuals or schematics. Schematics and manuals are not available for every product.

The level of specialized knowledge needed for repairs should be minimzed // No specialized knowledge needed for repairs.

One schematic searched online, of one specific DAC Chip

Electronic chips do not wear, life time of 50 years+

Elektrolytische Condensator (Elco)

> Elco's wear increases with heat, for every 10 degrees extra their lifespan decreases by 10 times. More expensive elco's have a longer lifespan to begin with. 1 CM can make a big difference.

Good/Bad design examples/developments

“NAD and Cambridge Audio amplifiers from the 2000’s are examples of bad designs and cheap components, there technical lifetime was short. The same brands made good designs in the 1990’s and still work, something which cannot be said for the 2000’s models”

Bad design – NAD Viso Two

- Everything crammed into the enclosure
- Insufficient heat dissipation possible
- Cheap Elco’s used to begin with
- Results in blown Elco’s. Can take out the screen or any other function.
- Not available on the second hand market anymore.

Good design – NAD 302

- Room for air to flow
- Distance between elco’s and heat generating components
- Can still be bough today
- Glass fuses in designated holders, can be replaced by the user, with little technical knowledge.

Appendix H – Stakeholders Wishes & Requirements.

Users

- Music Enthusiast
    - Wants to have full control over the system, to the degree he/she desires. Others should not be able to harm his system. Wants to be able to upgrade. Wants the units to retain value (in case of fast trade in for example)
- Significant Other
    - Wants to be able to play music and have a voice in the external appearance.
- Family members
    - Want to be able to play music (Loud), might have friends over who want to play something as well
- Cleaner
    - Must be able to do his work, should not be able to change something he should not.

Retail

- Sales agent
    - Explain to possible retailers what the system is, what's in it for them, unique selling points.
- Store employee
    - Needs to be able to demo the equipment, different setups, offer customer support

Manufacturers

- Audiohuis
    - Gain knowledge about customers. First steps towards first own amplifier.
- Electronics producer
    - Wants to show his product is used
- Components producer
    - Wants his chips and components to be used
- Enclosure manufacturer

Government (EU, Dutch Government

European Government

- *Concept must meet Energy regulations*
- *Concept must meet CE marking regulations*
- *Customs*

Dutch Government

- *Concept must meet local regulations*

Wecycle

- *Must be kept up to date regarding materials and recycling.*
- *Regulation collection and recycling of electrical equipment in the Netherlands*

Maintenance

- Repair technician
    - Quickly find the defect, replace faulty parts,
- Refurbish technician
    - Easy replacement of parts that wear
- Recycling
    - Easy disassembly of concept

Competitors

- Will try to replicate if it becomes a success.
- Might make some part better, can it be integrated?

Online Questionnaire

To map the preferences and needs of the customers two discovery methods are used: Online Questionnaires and In-depth interviews. The online questionnaire is a substitution for guided interviews. The COVID-19 pandemic limited the personal contact options and possibilities. The in-depth interviews are conducted in person, respecting the applicable safety guidelines.

“Questionnaires can be used in order gain insights in order to gain insight into the frequency with which certain perceptions/opinions/behaviours occur and into the level of interest of consumers into certain product or service concepts.“ (Boeijen, et al. 2013)

The goal of the Online questionnaire is to gain insights in a wide variety of aspects associated with HiFi.

Execution

The questionnaire is divided into five sections: Modular design, Wishes & Needs, Aesthetic preferences, General information and a wrap up. The questionnaire can be found in appendix K (English) and L (Dutch). Each section had their goal, which will be explained briefly.

Modular design

The aim of this section is to introduce participants to the research, and to modular products.

Wishes & Needs

In this section the participants are asked about; where and how they want to use the amplifier, which features they want, what kind of functions, and preferred way of purchasing.

Aesthetic preferences

The participants are asked to score nine current amplifiers, on a scale from 1 to 10, just like school grades. First based purely on aesthetics, second based on the perceived usability of the amplifier, ignoring other factors like functionality and costs.

General information

In this section general information was gathered, age, family composition and where and how they currently listen to music.

Wrap up

In the wrap up participants are thanked for their participation, and have the option for final remarks.

In the section ‘General information’ there was a hidden sub section, dedicated to Music Enthusiasts. They are invited to leave additional information, but also to partake in future research, starting with In-Depth interviews. More on those later.

All customers who visited AHD were invited to partake into the research, unfortunately this number is lower than it normally would have been, due to the 2020/2021 COVID-19 pandemic. If this was not the case they would have been asked to fill in the questionnaire in the store on the available iPads. However, to prevent cross contamination via the iPad an alternative is offered, a printed QR-code leading them to the questionnaire, see figure 10. This way of partaking was met positively, because they could fill it in at their own time and pace.

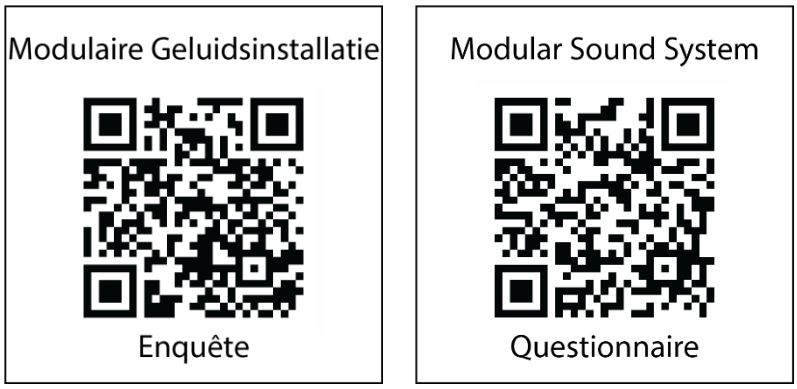


Figure 10: Invitation to partake in the Dutch and English online questionnaire.

Results

General

- All respondents indicate to be interested in the option of a modular amplifier solution. They are all willingly towards the concept idea.

Usage

Location

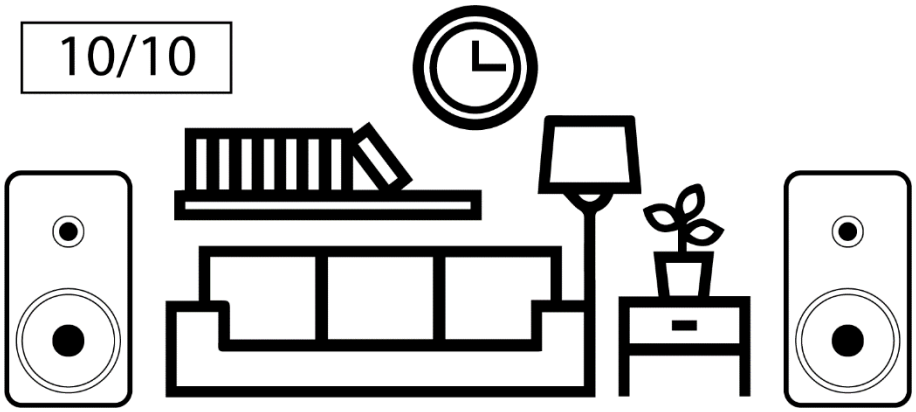


Figure 11: All respondents would use the HiFi solution in the living room

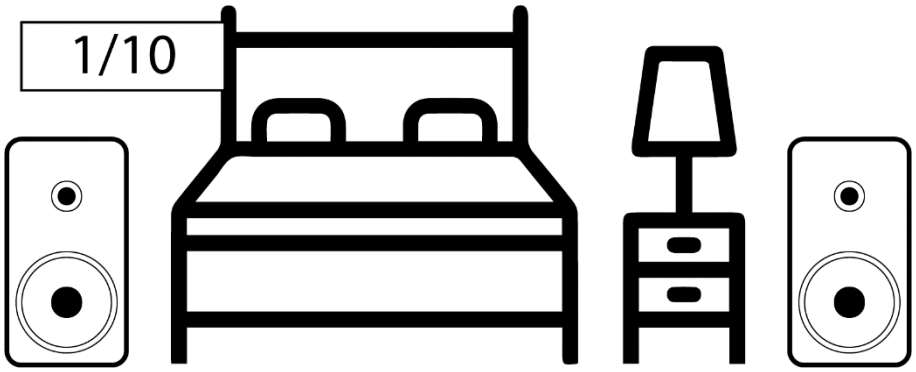


Figure 12: One respondent indicated he could use the HiFi solution in a bedroom

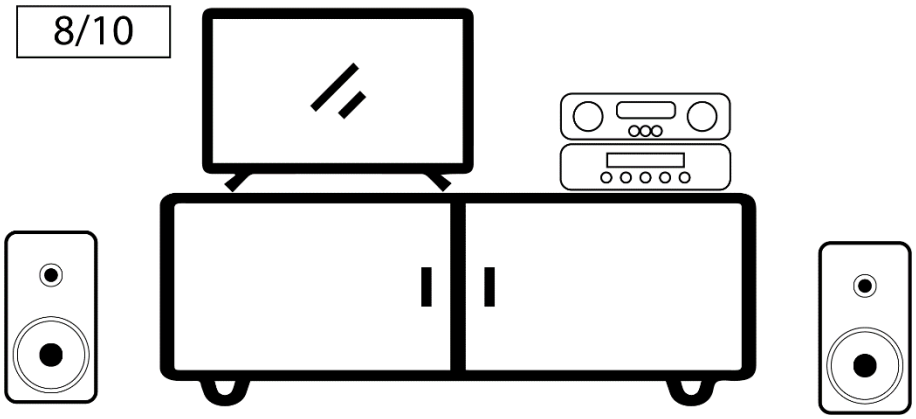


Figure 13: 80% of the respondents indicated that they would place the amplifier solution in plain sight.

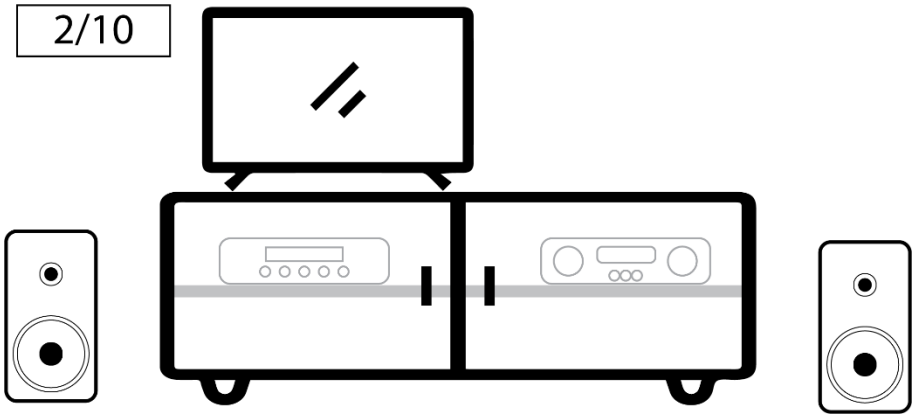


Figure 14: Two respondents indicated that they would place the amplifier solution in a cabinet. It has to be noted that they assumed the HiFi solution would not be pleasing to look at.

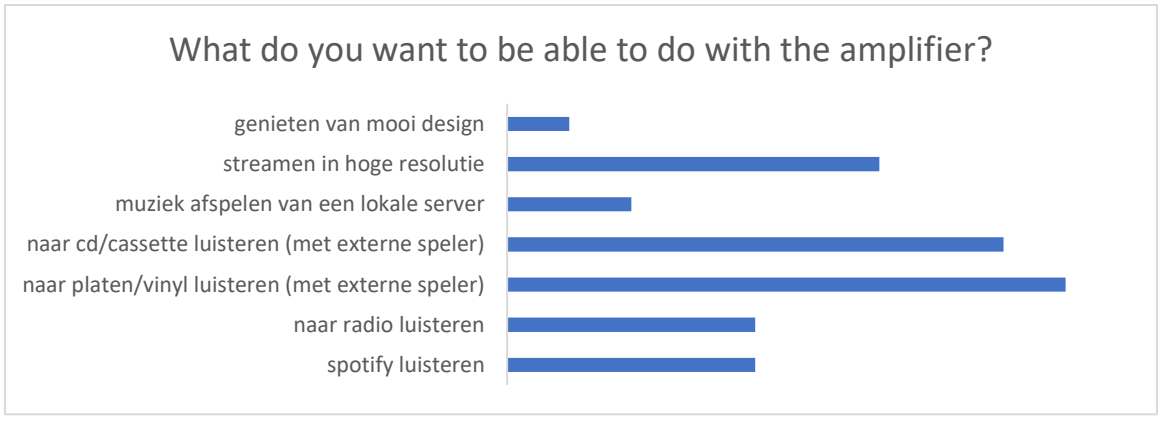


Table 1: Streaming, Radio, Vinyl, and other physical mediums are still in use.

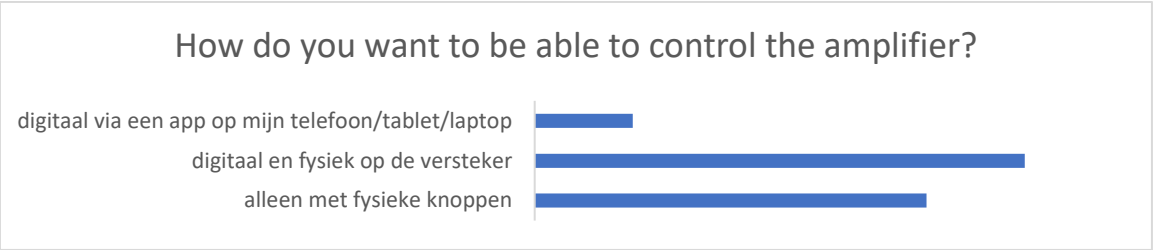


Table 2:

Only one respondent indicates to only want to be able to control the amplifier using an software application. The majority would like to be able to control amplifier solution using a software application, or via physical buttons. Age does not make a difference in this regard.

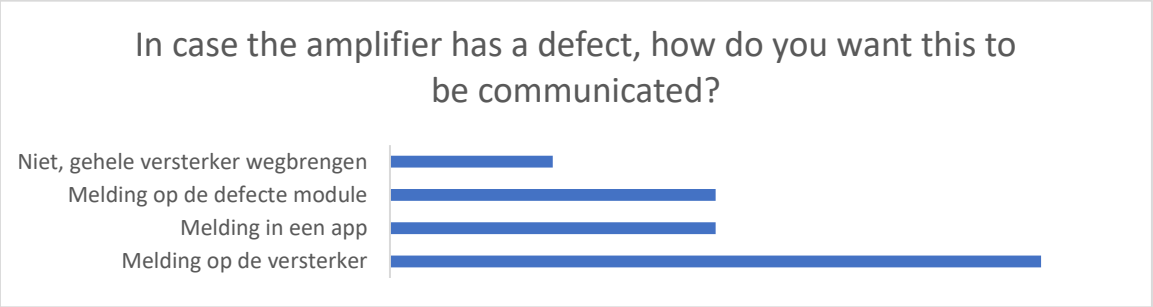


Table 3:

There is a preference for a defect to be communicated through the amplifier(front), however this seems to be age depended.

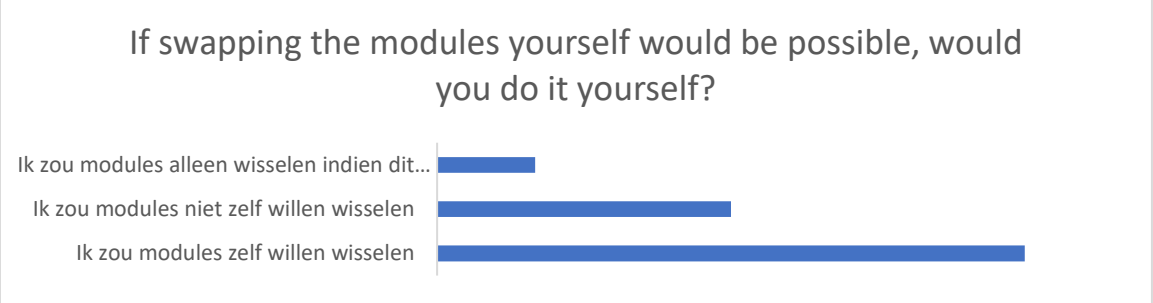


Table 4:

The majority of the respondents indicates to be willing to swap the modules themselves, even if this does not have an financial benefit. Age seems to be a factor in this case, the older respondents seem to choose the easier route and let it being taken care of.

Technical preferences

Functions

Different functions allow different musical sources to be used. Some functions are dependent of each other, for example; to be able to use a streamer a DAC is also needed. An overview of these dependencies can be found in appendix M.

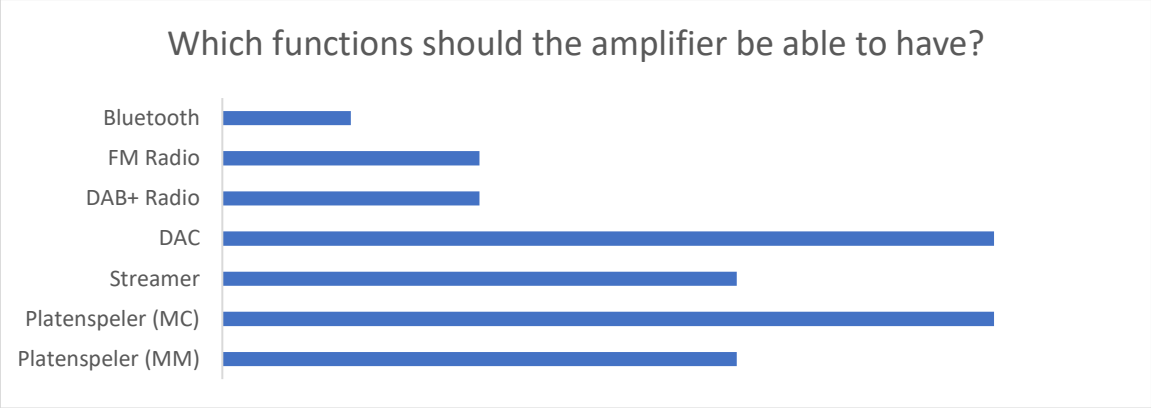


Table 5

Features

Features give the user the ability to tweak the sound to their liking in one way or another. The effects of the features are explained in Appendix M.

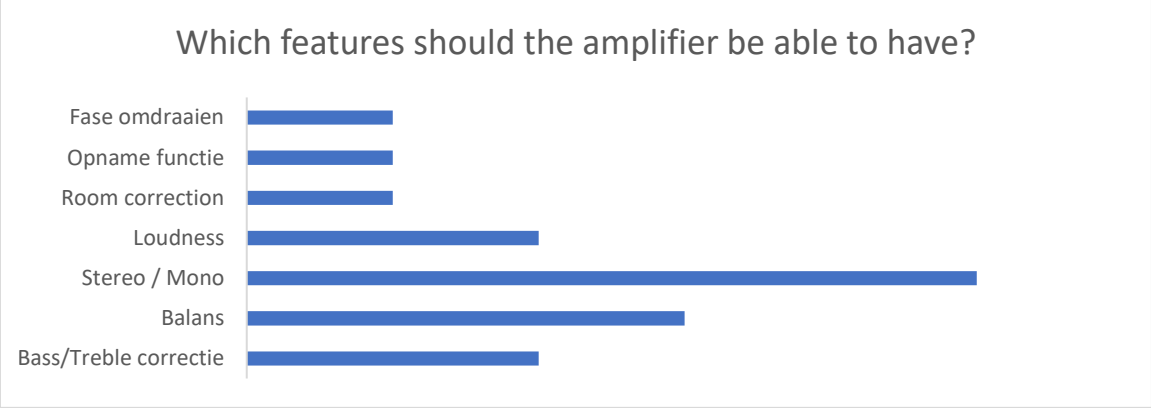


Table 6:

Connections

Connections are the link between external equipment and the different functions. The benefits and capabilities of the different connectors can be found in appendix M.

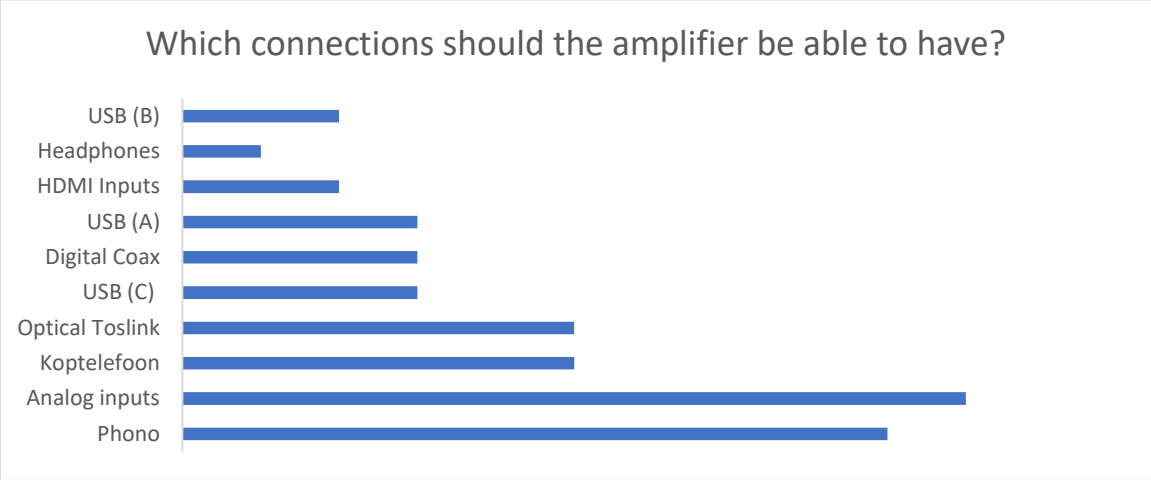


Table 7:

Aesthetical preferences

The participants were asked to rate nine current amplifiers, which can be seen in figure 15. The scores they gave each amplifier can be found in Appendix N – Aesthetics & Control preferences. The respondents group is to small to cluster aesthetical preferences, and perceived usability into user groups. For that the results were to far apart. However there are some observations to made, and conclusions to be drawn.

Figure 15: Amplifiers subjected to grading by the participants.

First of all the amplifier with no buttons scores the lowest, as can be seen in Figure 16. The NAD M10 is a true All-in-One solution and can only be controlled using the screen on the front, or the software application that can be installed on a phone, tablet or PC. Regarding perceived usability it scores below average as can be seen in Figure 17.

Amplifier 6 and 9, the Rega Elex R and Moonriver 404 respectively, score the best on perceived usability. The Rega has only 3 buttons, and the Moonriver has a symmetrical layout without difficult functions.

Amplifier 3 and 5 score the worst with regards to perceived usability. This are amplifiers from Luxman and Yamaha, they have buttons for all their different functionalities.

Finally it can be observed that dark colours are in favour over lighter colours.

Figure 16: Aesthetics preferences

Figure 17: Controll preferences

From the aesthetical preferences it can be concluded that the HiFi solution should have at least one physical button. Furthermore, the front of the amplifier should be customizable to fit the preferences of the different users. And the main part of the HiFi solution should have a dark colour. One final remark that was made is that sound quality will always remain decisive for the Music Enthusiast.

Aesthetical Preferences

1	2	3
 E: 8 B: 7	 E: 6 B: 7	 E: 8 B:8
4	5	6
 E: 8 B: 6	 E: 7 B: 8	 E: 8 B: 9
7	8	9
 E: 8 B: 8	 E: 8 B: 9	 E: 8 B: 9

1	2	3
E: 7 B: 7	 E: 8 B: 8	 E: 9 B:9
4	5	6
 E: 4 B: 6	 E: 7 B: 7	 E: 7 B: 7
7	8	9
 E: 6 B: 7	 E: 7 B: 7	 E: 9 B: 9

3	1	2
 E: 6 B: 6	 E: 6 B: 6	 E: 6 B:6
4	5	6
 E: 5 B: 5	 E: 5 B: 5	 E: 7 B: 7
7	8	9
 E: 6 B: 7	 E: 7 B: 7	 E: 8 B: 8

4	1	2
 E: 9 B: 8	 E: 7 B: 8	 E: 3 B:6
4	5	6
 E: 6 B: 6	 E: 4 B: 5	 E: 7 B: 7
7	8	9
 E: 7 B: 5	 E: 7 B: 6	 E: 9 B: 7

5	1	2
 E: 5 B: 7	 E: 8 B: 7	 E: 4 B:7
4	5	6
 E: 4 B: 9	 E: 9 B: 9	 E: 8 B: 6
7	8	9
 E: 6 B: 6	 E: 6 B: 9	 E: 8 B: 8

6	1	2
 E: 7 B: 8	 E: 7 B: 8	 E: 8 B:8
4	5	6
 E: 7 B: 9	 E: 8 B: 8	 E: 9 B: 9
7	8	9
 E: 6 B: 7	 E: 7 B: 7	 E: 5 B: 5

7 1  E: 8 B: 8	2  E: 7 B: 7	3  E: 8 B:5	8 1  E: 7.5 B: 7.5	2  E: 6.5 B: 7	3  E: 8.5 B:8.5
4  E: 7 B: 6	5  E: 4 B: 5	6  E: 3 B: 7	4  E: 7.5 B: 8	5  E: 8.5 B: 8.5	6  E: 7 B: 7
7  E: 8 B: 7	8  E: 7 B: 9	9  E: 7 B: 6	7  E: 8.5 B: 9	8  E: 7.5 B: 8	9  E: 8 B: 8
9 1  E: 8 B: 8	2  E: 6 B: 7	3  E: 4 B:4	10 1  E: 5 B: 5	2  E: 8 B: 7	3  E: 8 B:8
4  E: 9 B: 8	5  E: 6 B: 7	6  E: 9 B: 8	4  E: 7 B: 9	5  E: 6 B: 6	6  E: 7 B: 7
7  E: 7 B: 7	8  E: 8 B: 8	9  E: 5 B: 8	7  E: 4 B: 4	8  E: 5 B: 3	9  E: 6 B: 6

In-Depth Interviews

For the HiFi solution to be sustainable it has to stay with the users for a long duration, preferably for the duration of their Audio life. However, for a Music Enthusiast to willing to use the HiFi solution for such a duration, it has to fit their changing needs and wishes.

Execution

Music Enthusiast like their music, their equipment and in general they like to talk about it. To profit from the latter In-Depth interviews, on unguided interviews, is the selected data gathering method. The goal of these interviews is to gain insights into their motivations to make changes to their systems, what kind of changes they make and how often they make them.

The interviews took place at Audiohuis Delft, and one over the phone. Preferably there would have been more, however the global pandemic limited the possibilities. If possible more In-Depth interviews will follow.

Interview 1

Versterkers: Marantz amplifier ->(kwaliteit) NAD amplifier -> Sphinx integrated amplifier & Dual ipod Dock

Bronnen: Cd speler, logitech squeezebox (werd niet meer ondersteund, was hardwarematig goed, overgenomen), Yamaha streamer. Yamaha blind gekocht, niet eerst geluisterd, minder dan squeezebox maar “voldoet”.

Speakers: Denon-> peerless-> Translator

Speakers gereconed and gereviseerd, buitenkant en filter.

Gebruikt nu: Translator + Sphinx + Yamaha Streamer

- Alles heeft een nieuwe eigenaar gevonden
- Door kinderen was er geen tijd meer om naar muziek te luisteren, daarom dual aangeschaft, het was iets van geluid en makkelijk te bedienen.
- In de winkel uitgebreid muziek zitten luisteren, schrok van de invloed van softwarematig geluid regelen. Definitie valt weg.
- Hifi Klubben is sfeerloos en heeft geen kennis, koop dit want is het duurste.

Equipment History & Future Wishes

1. JVC receiver, 2nd hand purchase
2. Wharfdale speakers, bought new
3. NAD 3020 amplifier, Higher level of performance

4. NAD CD player, bought new

5. Peerless speakers, Higher level of performance

A. Started working at Translator, many models passed

6. Logitech Squeezebox (Streamer), missing function

7. Translator speakers, Higher level of performance

8. Sphinx Integrated Amplifier, Higher level of performance

B. Became parents

9. Ipod Classic, versatile in use

10. Ipod Dock, easy to use

11. NAD Cd player, replacement for defect

12. Replacement streamer, pervious lost software support

13. Analog pre amplifier, add missing function to the Sphinx(Remote)

Interview 2

Begonnen met audio: 10 jaar, cobiset cd en casette van opa en oma. Goed geluid gewend van thuis, B&O set. Bluetooth speakers gehad, voor thuis gebruik. Goede koptelfoon, steeds meer onderweg, wil van het draadje af, wel met goede codec. Via huisgenoot weer op versterker gekomen, had onkyo uit de jaren 80, uit de tijd dat alles van metaal was.

Eerst misstap, surround is toch ook voor muziek wel leuk, bleek niet zo te zijn. Surround versterker kan veel te veel, lastig instellen op speakers. Jaar mee gespeeld, toen klaar mee. Stap naar Elex R, met sponsoring, future proof nu duur maar niet direct willen upgraden. Harman Kardon AVR 126, surround samen met Wharfdale Diamond 220. Yahama tt300 eerste draaitafel, geupgrade naar P8, nooit meer wat aan veranderen. Alleen cartridge. Vienna acoustics beethoven grand reference symphony edition.

Huidig Rega Phono MC.

Toekomst:

Luxman 590, voor stap hoger, switching (classe D) niet zo mooi als classe A. Mist eigenlijk een tussenstap. Aethos logsiche tussenstap, dan 550 dan 590. Controle en diepte moet meer mogelijk zijn. Maximale uit luidsprekers halen, ondervonden tijdens demo.

Harman kardon nu weer ingebruik omdat hij een koptelefoon aansluiting heeft.

mist een DAC, voor digitaal aansluiten van CD-speler en Streamer en headphones amp. Cd speler voor de lol, niet naar zelfde niveau als platenspeler. DAC Cambridge audio 200m (400 a 500), voor functionaliteit, wil eigenlijk naar Audiolab Mdac+. Droom streamer Moon 390, einddoel. Naim, droog maar soundstage bizar, plaatsing is waanzinnig, analytisch. Geluid gaat voor breedte, gaat niet alleen om geld.

Pre Doel: Aura Reference MC, luxman 590 (509), vienna acoustics, rp8, met heleboel oude hifi meuk voor de hobby, voor de ervaring. Moon 390.

Huidig

Vienna niet ingebruik door verandering van huis. Geen plaats meer voor. Tijdelijk Klipsch rf5.

Tijdje naar streamer geluisterd, platenspeler geen plaats, was weer genieten toen hij analoog speelde.

Equipment History & Future Wishes

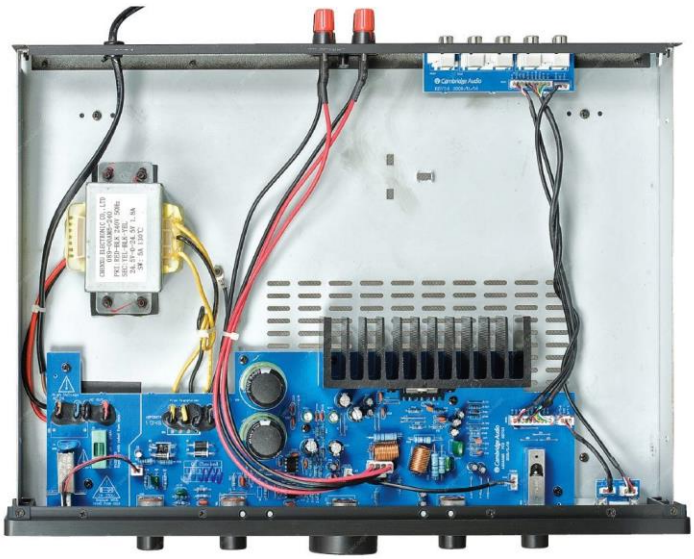
1. First stereo set, gifted by a relative.
2. Mono Bluetooth speaker, used on the move and at home
3. Audiophile headset, “affordable” and versatile (Higher performance)
4. Surround receiver, with abundant features (Functionalities)
5. 5.1 surround ‘satellite’ speaker set
6. First record player, gifted or 2nd hand (Wish for a medium)
7. First new bought Audiophile stereo speakers
8. Semi-High-End Analog audiophile integrated amplifier, bought to last
9. High-End Record player, bought for his Audio Life (Higher performance)
10. Audiophile MC Phono pre amplifier (Missing function)
11. High-End Stereo speakers, bought for his Audio Life (Higher Performance)
12. Basic streamer, bought due to lack of space (Missing function, ease of use)
13. Audiophile headphone amplifier (Missing Function)
14. Audiophile DAC & Bluetooth receiver (Missing function & higher level of performance)
15. High End Analog Integrated amplifier (Higher level of performance)
16. Dream setup, utilizing the High-End speakers to the fullest, with top of the line equipment, digital and analog.

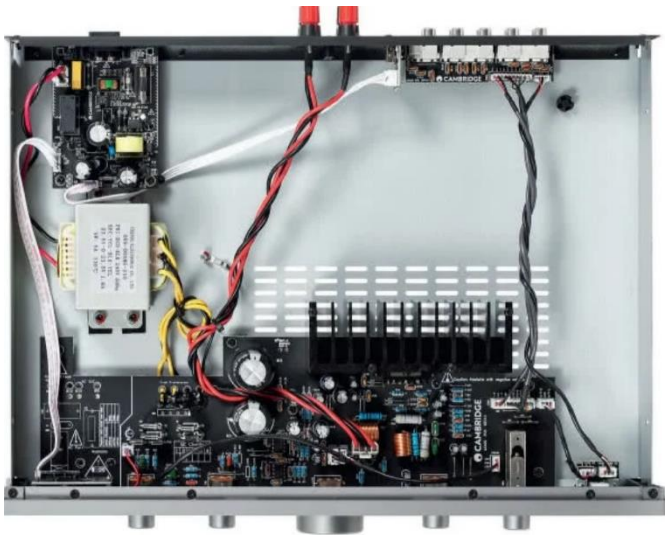
Appendix Q – Development of HiFi brands

Rega Brio Vs Rega Brio R

Cambridge AM 5- Cambridge AXA 25

The wish for a remote resulted in an additional PCB with a standby powersupply





Master Graduation Thesis - Modular Sound System

This survey is part of my Master Thesis project. I want to decrease music enthusiasts environmental impact during their audio life. I want to achieve this by adopting a modular design for an integrated amplifier. The modular design improves flexibility during its lifetime, allowing for personal input and the ability to adapt to a changing context.
The survey consists of five sections. You may stop at any moment, however your cooperation is much appreciated!

Section 1: Modular design
Section 2: Wishes & Needs
Section 3: Aesthetics Research
Section 4: General information
Section 5: Wrap up

All data collected from this questionnaire will solely be used for this study. It will be processed and saved anonymously. The data will be removed on: 03-05-2021.
*Vereist

1. Do you agree with the previously mentioned? *

Markeer slechts één ovaal.

- ◯ Yes
- ◯ No

Modular products

Currently we are living in a linear economy, we buy, use, replace and throw away. In a circular economy we strive to minimize replacing and throwing away, by upgrading, repairing, reusing and recycling. Modular products help us reach a circular economy, by designing products that are made to be upgraded and repaired.

2. Are you familiar with modular products? *

Markeer slechts één ovaal.

- ◯ Yes *Ga naar vraag 3*
- ◯ No (Select this option for more information about modular products)
  Ga naar sectie 3 (Modular products explained)

Modular products explained

Three pictures are shown to illustrate the possibilities of modular design. These are just examples, since modular design can be applied to almost every product category, and are meant to give you an idea of the possibilities.

The first picture shows project Ara by Google, a modular smartphone design. Everything is placed in its own compartment, making it possible to swap the battery, camera or speaker, depending on your current preferences. For example; if you go to a tourist attraction, you can swap your camera for a better one.

The second picture shows a kitchen system by IKEA. It has multiple modules that can be combined to the preferred size and functionalities and fill the available space, without resorting to a custom made kitchen.

The third picture shows a modular headphone by Gerrard Street. If part of the headphone breaks they replace it for free. It is “free” because Gerrard Street uses a different payment method, you can only lease their headphones and pay per month. Therefore replacing a broken part is a service, part of the monthly fee, comparable to a lease car.

Google - Project Ara - Modular Smartphone

Ikea - Knoxhult - Modular Kitchen

Gerrard Street - Boss - Modular Headphone

Modular Integrated Amplifier

Modular product design allows for complete new product designs. Traditional rules can be broken and revised. A modular amplifier can adjust to your needs and wishes, at purchase or in later stages. Since it is a complete new product I am curious about your preferences concerning a modular amplifier, now that everything is possible.

3. What is your first thought about a modular integrated amplifier? *

Wishes & Needs

For the modular integrated amplifier to suite your wishes and needs the following questions are about you.

4. What do you want to be able to do? *

Vink alle toepasselijke opties aan.

- [ ] Listen to radio
- [ ] Play a vinyl record (using an external player)
- [ ] Listen to Spotify
- [ ] Listen to a CD / Cassette (using an external player)
- [ ] Play music from a local server
- [ ] Stream High res
- [ ] Anders: _____

5. How do you want to be able to control the amplifier?

Markeer slechts één ovaal.

- ◯ Digitally using an app on your phone/tablet/pc
- ◯ Digital and with Physical buttons on the amplifier
- ◯ Only physical buttons on the amplifier
- ◯ Anders: _____

6. Which functions would you want to be able to have? *

Vink alle toepasselijke opties aan.

- [ ] I don't know
- [ ] Streamer
- [ ] DAC (Digital to Analog Converter)
- [ ] Phono amplifier (MM)
- [ ] Phono amplifier (MC)
- [ ] DAB+ Radio
- [ ] FM Radio
- [ ] Internal Storage
- [ ] Anders: _____

7. Which features would you want to be able to have? *

Vink alle toepasselijke opties aan.

- [ ] I don't know
- [ ] Room correction
- [ ] Bass/Treble correction
- [ ] Balance Control
- [ ] Fase correction
- [ ] Stereo / Mono modes
- [ ] Loudness
- [ ] Screen
- [ ] Anders: _____

8. Which connections would you want to be able to have? *

Vink alle toepasselijke opties aan.

- [ ] I don't know
- [ ] Phono
- [ ] Digital Coax
- [ ] Optical Toslink
- [ ] HDMI Arc
- [ ] HDMI Inputs
- [ ] USB (B)
- [ ] USB (A)
- [ ] USB (C)
- [ ] Analog inputs
- [ ] AES/EBU
- [ ] Record In/Out
- [ ] Anders: _____

Wishes & Needs: Upgrading

Modular products are made of several individual modules, linked together, to fulfill their combined function. A modular integrated amplifier needs at least a power supply module, a pre amplifier module and a power amplifier module. Next to those three other modules can be integrated, for instance a DAC, a phono amplifier, or a HDMI board. Swapping a module can be done to upgrade the amplifier, achieving a higher level of performance, or because a module broke and needs to be repaired. The following questions are about these modules.

9. For which Functions and Features would you want to have a module?

10. Which modules would you want to be able to upgrade to achieve a higher level of performance?

11. In case a module needs repairing, how do you want this to be communicated?

Markeer slechts één ovaal.

- ◯ Via a notification in an application
- ◯ By a warning light on the amplifier
- ◯ By a warning light on the module
- ◯ I don't, in case something does not work I bring it to the shop
- ◯ Anders: _____

12. If swapping the modules yourself would be possible, would you do it yourself? *

Markeer slechts één ovaal.

- ◯ Yes, I would do it myself
- ◯ Yes I would do it myself, but only if it costs money to have it done
- ◯ No, I would not do it myself
- ◯ No I would not do it myself, not even for a discount

Wishes & Needs: Where & When

13. In what kind of room would you use a modular amplifier? (Living, Study, etc...) *

14. Where would you place the integrated amplifier? (In plain sight, in a cabinet, etc.)

15. Would you want the modulair integrated amplifier to be:

Markeer slechts één ovaal.

- All in one enclosure
- Two parts/modules
- Three parts/modules

Wishes & Needs: Purchase

A circular economy and modular product designs allow for different ways of “owning” products. Traditionally we buy the products we use and need, from the food we eat and the bike we use, to the house we live in and the car we drive. However over the recent years new ways of paying have emerged; Pay per Use and Leasing. The three ways of using a product, in case of a modular amplifier, result in the following options:

Paying per use; for example for each hour you listen to music.
Lease; lease every module individually and pay a resulting fixed amount per month
Traditional buying; you buy each module and trade in your previously owned module.

16. What value could a modular amplifier reach

Vink alle toepasselijke opties aan.

- [ ] €500 - 1000
- [ ] €1000 - 1750
- [ ] €1750 - 2500
- [ ] €2500 - 3500
- [ ] €3500 - 4500
- [ ] €4500 - 5500
- [ ] €5500 - 9999
- [ ] €9999+

17. If you were to obtain a modular amplifier; which way of purchasing would have your preference? *

Vink alle toepasselijke opties aan.

- [ ] Pay per Use
- [ ] Leasing
- [ ] Buying

Current Audio Products

The following section focusses on your personal preference regarding current designs. What is your opinion on the nine amplifiers portrayed below. The first question asks you to grade the amplifier with regards to aesthetics, how much do they appeal to you. Secondly you are asked to grade the amplifier regarding usability. How usable is it to you, grade from 1 to 10, just like in school. 10 could not be better, 5.5 is a minimum to pass. Each of the amplifiers will come by one by one, you are asked not to change your answers after continuing to the next.

Overview of nine Integrated Amplifiers

Current Audio Products

18. Aesthetics: Grade (1-10) *

19. Controls: Grade (1-10) *

20. Remarks?

21.

Markeer slechts één ovaal.

Optie 1

Current Audio Products

22. Aesthetics: Grade (1-10) *

23. Controls: Grade (1-10) *

24. Remarks?

Current Audio Products

25. Aesthetics: Grade (1-10) *

26. Controls: Grade (1-10) *

Current Audio Products

27. Aesthetics: Grade (1-10) *

28. Controls: Grade (1-10) *

Current Audio Products

29. Aesthetics: Grade (1-10) *

30. Controls: Grade (1-10) *

Current Audio Products

31. Aesthetics: Grade (1-10) *

32. Controls: Grade (1-10) *

Current Audio Products

33. Aesthetics: Grade (1-10) *

34. Controls: Grade (1-10) *

Current Audio Products

35. Aesthetics: Grade (1-10) *

36. Controls: Grade (1-10) *

Current Audio Products

37. Aesthetics: Grade (1-10) *

38. Controls: Grade (1-10) *

Current Audio Products

Which one would you consider buying, pleas select 3

39. *

Vink alle toepasselijke opties aan.

☐ 1

☐ 2

☐ 3

☐ 4

☐ 5

☐ 6

7

8

9

40. Please elucidate on your selection, if you want.

General information

41. What is your age? *

Markeer slechts één ovaal.

- < 20
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70-79
- 80-89
- 90-99

42. Where and how do you listen to music? *

Vink alle toepasselijke opties aan.

- On the move using headphones (Bike, Train, Gym, Work, etc.)
- On the moving using a speaker (Phone speaker, Bluetooth speaker, etc.)
- At home, Stereo (Two speakers in the: Kitchen, living room, etc.)
- At home, Mono (Bluetooth speaker, Phone, etc.)
- At home, Surround (5.1, 7.1, etc.)

Anders: _____

43. What is your (biological) gender *

Markeer slechts één ovaal.

- Male
- Female
- I'd rather not say

44. What is your family composition?

_____

45. Do you Play a musical instrument *

Markeer slechts één ovaal.

- ◯ Yes
- ◯ No

46. Do you turn on music (Spotify, radio, ect.) yourself? *

Markeer slechts één ovaal.

- ◯ Yes
- ◯ No

47. When do you turn on music?

_____

48. Are you at home the: *

Markeer slechts één ovaal.

- ◯ Music Enthusiast *Ga naar vraag 49*
- ◯ Partner of a music enthusiast *Ga naar vraag 51*
- ◯ Family member of a music enthusiast *Ga naar vraag 51*
- ◯ Friend of the family *Ga naar vraag 51*
- ◯ Anders: _____

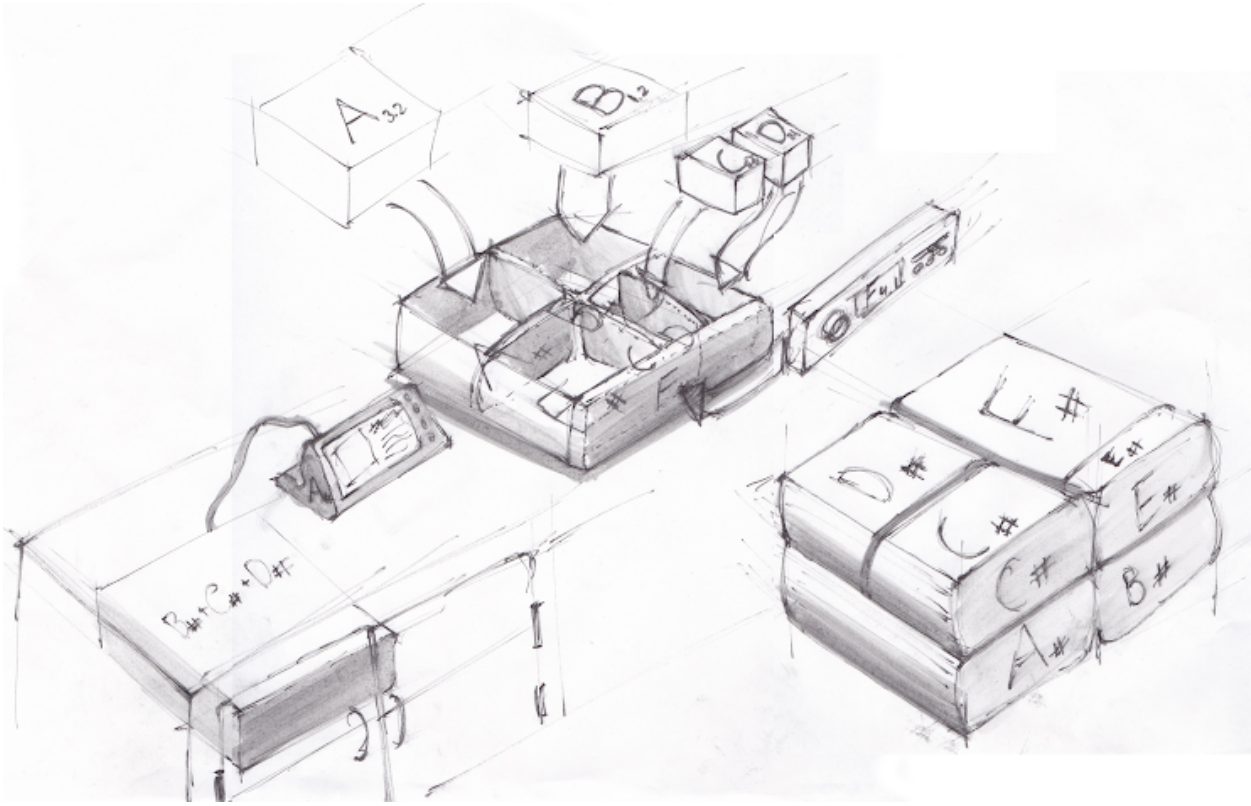
Music Enthusiasts

49. Dear Music Enthusiast, thank you for filling in the questionnaire till this point. This question is specially for you. For my research I would like to sit down with you one on one, discussing you audio history, present and future, amongst other things. If you would like to be part of this and help shape the future please leave your (first) name and email address for me to contact you directly.

50. If you do not want to partake in future research, but do have remarks, questions, ideas, opinions, feel free to leave them below.

Wrap up

51. After this questionnaire, would you be interested in a modular integrated amplifier? *



Markeer slechts één ovaal.

- Yes
- No

52. Do you have any remarks I missed, questions you want answering, information I should have? Please feel free to leave it below, I will read it all.

Wrap up: Future Research

For my graduation thesis I will be conducting other little questionnaires and experiments like you just participated in, for which I could use your help again. I would appreciate it if I may contact you for future research in the next few months. If so, please leave your (first) name and email address below. You are not obliged to anything if you do.

53. (First) Name + Email address

Thank you for your participation

That was it, many thanks for your participation till the end!

Afstudeerscriptie – Modulaire Geluidsinstallatie

Helpt u mee om de toekomst van HiFi vorm te geven?

Middels deze enquête wordt de toekomst van een modulaire versterker onderzocht. Een versterker die met u meegroeit en die zich continu kan aanpassen aan uw wensen en behoefte op een bepaalt moment. Zo stelt u na verloop van tijd uw eigen versterker samen of past u de versterker naar wens aan. Gaat er een module kapot of biedt een nieuwe technologie meerwaarde? Dan kan slecht dat ene onderdeel vervangen worden in plaats van de gehele versterker. Een modulair ontwerp maakt de versterker langer inzetbaar, personaliseerbaar en maakt het mogelijk de versterker aan te passen aan een veranderende context. Duurzaam, toekomstbestendig en minder milieubelastend.

Middels deze enquête kunt u uw wensen en behoefte met betrekking tot een geïntegreerde versterker delen. De enquête bestaat uit vijf secties. Stoppen kan op elk moment, maar het volledig invullen wordt zeer gewaardeerd. In totaal duurt het invullen van de enquête ongeveer 20 minuten.

Sectie 1: Modulaire producten
Sectie 2: Wensen en Behoeften
Sectie 3: Esthetisch onderzoek
Sectie 4: Algemene informatie
Sectie 5: Vervolgonderzoek

De uitkomsten van deze enquête zullen worden gebruikt voor wetenschappelijk onderzoek vanuit de TU Delft naar de toepassing van een modulair ontwerp op een geïntegreerde versterker. Alle data wordt anoniem verwerkt en opgeslagen. De data wordt verwijdert op: 03-05-2021.
*Vereist

1. Gaat u akkoord met het bovenstaande? *

   Markeer slechts één ovaal.

   - ◯ Ja
   - ◯ Nee

Modulaire producten

Momenteel leven we in een lineaire economie; we kopen, gebruiken, vervangen en gooien weg. In een circulaire economie streven we ernaar om vervangen en weggooien te minimaliseren door: te upgraden, repareren, hergebruiken en recyclen. Modulaire producten helpen om een circulaire economie te realiseren.

2. Bent u bekend met modulaire producten? *

Markeer slechts één ovaal.

- ◯ Ja *Ga naar vraag 3*
- ◯ Nee (Kies deze optie als u meer informatie over modulaire producten wilt)
  Ga naar sectie 3 (Modulaire producten toegelicht)

Modulaire producten toegelicht

De drie onderstaande afbeeldingen illustreren de mogelijkheden van modulaire ontwerpen. Het zijn slechts voorbeelden, aangezien modulair ontwerpen op ongeveer elk product kan worden toegepast, maar het geeft een idee van de mogelijkheden.

In de eerste afbeelding ziet u project Ara van Google, een modulair smartphone ontwerp. Elk onderdeel is in een eigen compartiment gestopt en kan zo eenvoudig vervangen worden. Zo kan je een grote batterij en gps modulen installeren tijdens een hike en een goede camera en extra geheugen op vakantie.

Afbeelding twee is modulaire keuken van Ikea genaamd Knoxhult. Door verschillende modules te combineren kan voor elke afmeting een passende keuken gemaakt worden, geheel volgens de wensen van de gebruiker.

De derde afbeelding is van de modulaire koptelefoon van GerrardStreet, Boss. Als een onderdeel van de koptelefoon stuk gaat wordt deze gratis vervangen. Je least deze koptelefoon namelijk, dus hij is niet van jouw, maar gratis reparatie zit er bij in. Het is vergelijkbaar met een leaseauto.

Google - Project Ara - Modulaire Smartphone

Ikea - Knoxhult - Modulaire keuken

Gerrard Street - Boss - Modulaire Koptelefoon

Modulaire Geïntegreerde versterker

Modulair producten ontwerpen staat ons toe om compleet nieuwe ontwerpen toe te passen, traditionele regels kunnen gebroken en herzien worden. Een modulaire versterker kan geheel voldoen aan jou eisen en wensen bij aanschaf, of in een later stadium doordat hij aanpasbaar is. Aangezien het een geheel nieuw product is ben ik benieuwd naar uw voorkeuren betreffende een geïntegreerde versterker, nu alles mogelijk is.

3. Wat is uw eerste gedachte over een modulaire versterker? *

Wensen & Eisen

Om de modulaire geïntegreerde versterker uiteindelijk op uw voorkeuren aan te laten sluiten gaan de volgende paar vragen over u.

4. Wat wilt u met de versterker kunnen doen *

Vink alle toepasselijke opties aan.

- [ ] Naar radio luisteren
- [ ] Naar platen/vinyl luisteren (met een externe speler)
- [ ] Spotify luisteren
- [ ] Naar een Cd / Cassette luisteren (met een externe speler)
- [ ] Muziek afspelen van een lokale server
- [ ] Streamen in hoge resolutie

Anders: [ ] _____

5. Hoe wil je de versterker kunnen bedienen?

Markeer slechts één ovaal.

- ◯ Digitaal via een app op mijn telefoon/tablet/laptop
- ◯ Digitaal en Fysiek op de versterker
- ◯ Alleen met fysieke knoppen
- ◯ Anders: _____

6. Welke functies zou je willen kunnen hebben? *

Vink alle toepasselijke opties aan.

- [ ] Ik weet het niet
- [ ] Streamer
- [ ] DAC (Digital to Analog Converter)
- [ ] Platenspeler (MM)
- [ ] Platenspeler (MC)
- [ ] DAB+ Radio
- [ ] FM Radio
- [ ] Interne opslag

Anders: [ ] _____

7. Welke features wil je dat de modulaire versterker kan hebben? *

Vink alle toepasselijke opties aan.

- [ ] Ik weet het niet
- [ ] Room correction
- [ ] Bass/Treble correctie
- [ ] Balans
- [ ] Fase omdraaien
- [ ] Stereo / Mono
- [ ] Loudness
- [ ] Scherm
- [ ] Anders: _____

8. Welke aansluitingen wil je kunnen hebben *

Vink alle toepasselijke opties aan.

- [ ] Ik weet het niet
- [ ] Phono
- [ ] Digital Coax
- [ ] Optical Toslink
- [ ] HDMI Arc
- [ ] HDMI Inputs
- [ ] USB (B)
- [ ] USB (A)
- [ ] USB (C)
- [ ] Analog inputs
- [ ] AES/EBU
- [ ] Record In/Out
- [ ] Koptelefoon
- [ ] Anders: _____

Wensen & Eisen: Upgraden

Modulaire producten worden opgebouwd uit verschillende modules die, wanneer goed verbonden, samen een taak vervullen. Een modulaire geïntegreerde versterker heeft op zijn minst drie modules nodig: een voor- en eindversterker en een voeding. Daarnaast kunnen anderen modules geïntegreerd worden, bijvoorbeeld een DAC, platenspeler versterker of HDMI board. Het verwisselen van modules kan worden gedaan om de versterker te upgraden, of omdat een module kapot is en gerepareerd moet worden. De volgende vragen gaan over zulke modules.

9. Voor welke functies en features zou je een module willen hebben?

10. Welke modules zou je willen kunnen upgraden, om op een hogere niveau te gaan spelen?

11. Indien er een module gerepareerd moet worden, hoe wilt u dit gecommuniceerd hebben?

Markeer slechts één ovaal.

- ◯ Door een melding in een app
- ◯ Door een melding op de versterker
- ◯ Door een melding op de defecte module
- ◯ Niet, zodra iets niet werkt breng ik de hele versterker weg
- ◯ Anders: _____

12. Als je de modules zelf zou kunnen wisselen, zou je dit dan doen? *

Markeer slechts één ovaal.

- ◯ Ja, ik zou het zelf doen
- ◯ Ja ik zou het zelf doen, maar alleen als het geld kost om het te laten doen
- ◯ Nee, ik zou het niet zelf doen
- ◯ Nee ik zou het niet zelf doen, zelfs niet voor een korting.

Wensen & Eisen: Waar & HOe

13. In welke kamer zou je een modulaire versterker gebruiken? (Woonkamer, studeerkamer, etc...) *

_____

14. Waar zou je de versterker plaatsen? (In het zicht, in een kast, etc...) *

_____

_____

_____

_____

_____

15. Zou je willen dat de versterker

Vink alle toepasselijke opties aan.

- [ ] In een kast zit
- [ ] Twee delen/modules
- [ ] Drie delen/modules

Anders: [ ] _____

Wensen & Eisen: Aanschaf

Een circulaire economie en modulaire producten staan ons toe om producten op een andere manier te bezitten. Traditioneel gezien kopen we de producten die we nodig hebben, van ons eten tot onze fiets en van ons huis tot onze telefoon. De laatste jaren zijn er nieuwe manieren van product bezig in opkomst; Pay per Use en Leasen. Voor een modulaire versterker kan dit op het volgende neerkomen:
Kopen: Je koopt elke module los en kunt ze inruilen bij aanschaf van een nieuwe.
Lease; je least de modules en betaalt een vast bedrag per maand/jaar
Pay per use: je betaalt per gespeeld uur.

16. Welke waarde kan zo’n systeem van jou bereiken?

Vink alle toepasselijke opties aan.

- [ ] €500 - 1000
- [ ] €1000 - 1750
- [ ] €1750 - 2500
- [ ] €2500 - 3500
- [ ] €3500 - 4500
- [ ] €4500 - 5500
- [ ] €5500 - 9999
- [ ] €9999+

17. Als je een modulaire versterker zou aanschaffen, welke vorm zou dan je voorkeur hebben? *

Vink alle toepasselijke opties aan.

- [ ] Buying
- [ ] Leasing
- [ ] Pay per Use

Current Audio Products

Wat is uw persoonlijk mening omtrent de negen onderstaande geïntegreerde versterkers. In de eerste vraag wordt u gevraagd om hem esthetisch te beoordelen, wat vind u er van? Ten tweede wordt u gevraagd wat u van de bediening vindt. Hoe bruikbaar is hij voor u, scoren op een schaal van 1 tot 10, net als op school. 10 kan niet beter, 5.5 is een minimum om te passeren. Elke versterker komt een voor een voorbij, u wordt verzocht niet terug te gaan en u antwoorden te veranderen.

Overzicht van negen geïntegreerde versterkers

Hedendaagse versterkers

18. Esthetisch (Cijfer 1-10) *

19. Bruikbaarheid (Cijfer 1-10) *

20. Opmerkingen

Hedendaagse versterkers

21. Esthetisch (Cijfer 1-10) *

22. Bruikbaarheid (Cijfer 1-10) *

23. Opmerkingen:

Hedendaagse versterkers

24. Esthetisch (Cijfer 1-10) *

25. Bruikbaarheid (Cijfer 1-10) *

26. Opmerkingen

Current Audio Products

27. Esthetisch (Cijfer 1-10) *

28. Bruikbaarheid (Cijfer 1-10) *

29. Opmerkingen

Hedendaagse versterkers

30. Esthetisch (Cijfer 1-10) *

31. Bruikbaarheid (Cijfer 1-10) *

32. Opmerkingen

Hedendaagse versterkers

33. Esthetisch (Cijfer 1-10) *

34. Bruikbaarheid (Cijfer 1-10) *

35. Opmerkingen

Hedendaagse versterkers

36. Esthetisch (Cijfer 1-10) *

37. Bruikbaarheid (Cijfer 1-10) *

38. Opmerkingen

Hedendaagse versterkers

39. Esthetisch (Cijfer 1-10) *

40. Bruikbaarheid (Cijfer 1-10) *

41. Opmerkingen

Hedendaagse versterkers

42. Esthetisch (Cijfer 1-10) *

43. Bruikbaarheid (Cijfer 1-10) *

44. Opmerkingen

Hedendaagse versterkers

Welke drie versterkers zou u tussen kiezen bij aanschaf?

45. *

Vink alle toepasselijke opties aan.

1

2

3

4

5

6

☐ 7

☐ 8

☐ 9

46. Ik wil u verzoeken u keuze hier toe te lichten, maar verplicht u niet.

General information

47. Wat is uw leeftijd? *

Markeer slechts één ovaal.

- < 20
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70-79
- 80-89
- 90-99
- 99+

48. Waar en Wanneer luistert u naar muziek? *

Vink alle toepasselijke opties aan.

- [ ] Onderweg met koptelefoon (Fiets, Trein, Sportschool, Werk, etc...)
- [ ] Onderweg mono (speaker in je telefoon / bluetooth speaker)
- [ ] Onderweg stereo (Auto)
- [ ] Thuis, stereo (Twee luidsprekers in de; woonkamer, keuken, slaapkamer, etc...)
- [ ] Thuis, mono (Bijvoorbeeld met een bluetooth speaker)
- [ ] Thuis, surround (5.1, 7.1, etc...)

Anders: [ ] _____

49. Wat is uw (biologisch) geslacht *

Markeer slechts één ovaal.

- Man
- Vrouw
- Zeg ik liever niet

50. Wat is uw gezinssamenstelling?

51. Speelt u een muziekinstrument? *

Markeer slechts één ovaal.

- Ja
- Nee

52. Zet u zelf wel eens muziek (Spotify, radio, ect..) aan? *

Markeer slechts één ovaal.

- Ja
- Nee

53. Wanneer zet u muziek aan?

54. Bent u thuis de: *

Markeer slechts één ovaal.

- Muziek liefhebber *Ga naar vraag 55*
- Partner van de muziek liefhebber *Ga naar vraag 57*
- Familie lid van de muziek liefhebber *Ga naar vraag 57*
- Vriend / Kennis *Ga naar vraag 57*

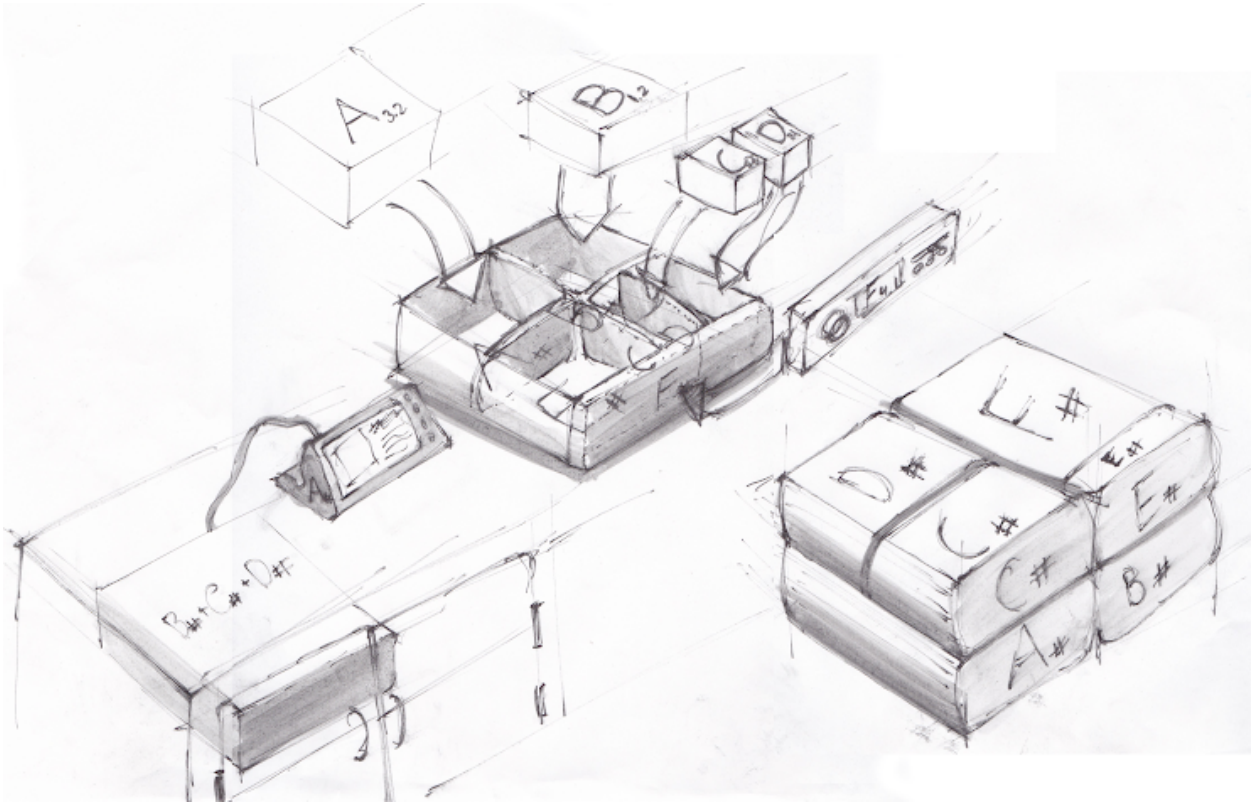
Muziek Enthousiasteling

55. Beste muziek enthousiastelingen, dank u wel voor het invullen van deze enquête tot dit punt. Deze vraag is speciaal voor jullie. Voor mijn onderzoek wil ik graag met u samen in gesprek om het te hebben over uw audio verleden, heden en toekomst, onder anderen. Als je hier onderdeel van wil uitmaken en helpen de toekomst vorm te geven laat dan je (voor) naam achter en email adres, zodat ik contact met je op kan nemen.

56. Als u niet persoonlijk in gesprek wilt, maar wel nog niets kwijt wilt; ideeën, vragen of een mening kunt u dat hieronder doen. Ik hoor het graag.

Vervolg onderzoek

57. Na deze enquête, zou u geïnteresseerd zijn in een modulaire geïntegreerde versterker? *



Markeer slechts één ovaal.

- Ja
- Nee

58. Heeft u nog opmerkingen, vragen waar u een antwoord op wilt, overige informatie, dan kunt u die hieronder achterlaten.

Vervolg onderzoek

Voor mijn afstudeeronderzoek zal ik nog meer korte enquêtes en experimenten uitvoeren, vergelijkbaar met wat u zojuist heeft gedaan. Hiervoor kan ik uw hulp wederom goed gebruiken. Indien ik u hier in de nabije toekomst over mag benaderen laat dan hieronder je (voor) naam en emailadres achter. U bent tot niets verplicht hierna.

59. (Voor) naam + e-mailadres

Hartelijk dank voor uw medewerking

Dat was het, hartelijk dank voor uw deelname!

Appendix K: Design Challenge Exploration

Base

What are the functions of the base?

What are the requirements of the base?

Which configurations can be made, based on research, expectations of the base?

Which layouts can be made, based on configurations of the base?

What kind of sustainable design can be applied to the base?

How can the connection between the base and the modules be made?

How can the infrastructure layer be integrated in the base?

Building Blocks

What are the functions of the Building Blocks?

What are the requirements of the building blocks?

How can the building blocks be sustainable?

How can the building blocks be connected to the base?

How can this connection be durable of the BB?

How can this connection be made by the user, without mistakes of the BB?

Can the connection be flexible of the BB?

Exterior Layer

What are the functions of the exterior layer (EL)?

What are the requirements of the EL?

Is an exterior layer needed? For correct functioning?

Is the exterior layer wished/needed by the user?

How can the EL be changed to match aesthetical preferences

How can the EL be sustainable

What kind of sustainable design needs to be applied to the EL.

Infrastructure Layer

What are the requirements of the IL?

How can the IL be integrated in the Base?

How can the IL be placed by the user?

How can the connection be flexible in use in the IL?

How can the connections be durable, reuse in the IL?

How can damaged cables be prevented / replaced in the IL?

What is the suitable medium for the signal distribution?

How can wrong connections be prevented in the IL?

User Interface

What is the function of the UI?

Which functions can/need to be in the UI?

What are the dimensions of the functions in the UI?

Which functions can be combined, does it all fit in the UI?

What are the module requirements of the UI?

Which connections are needed in the UI?

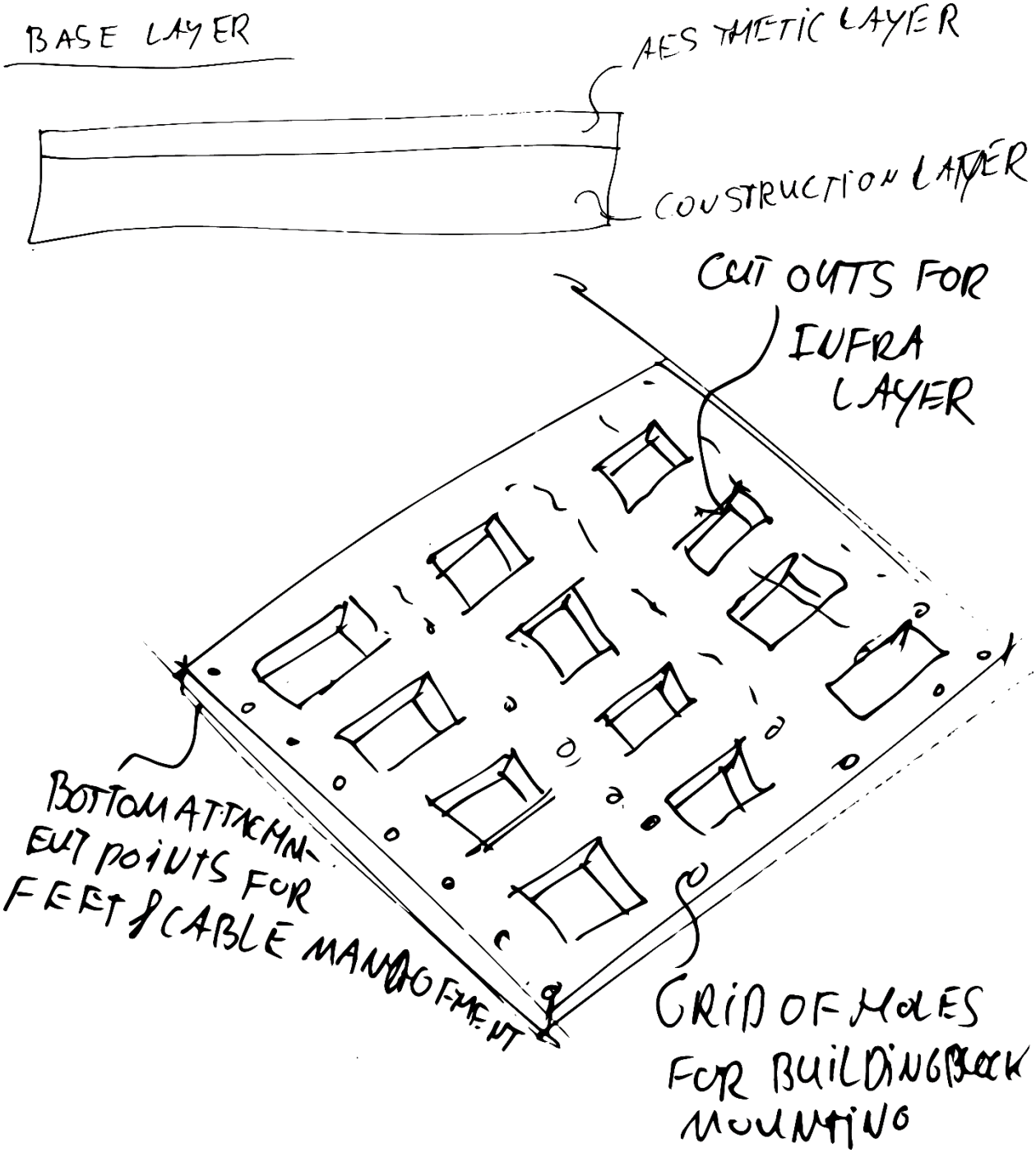
What do the modules look like in the UI?

How are the modules mechanically connected to the UI?

How can the aesthetics of the UI be changed?

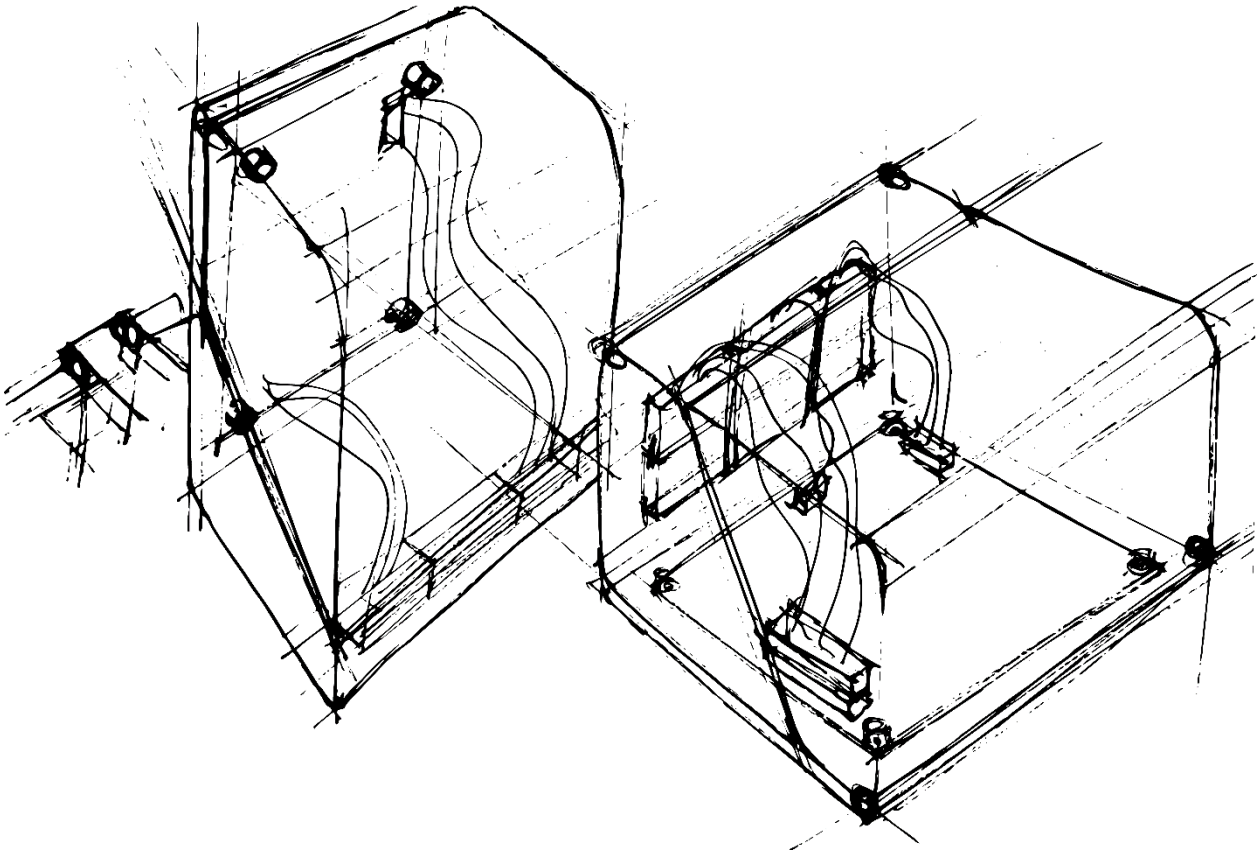
What are the UI Requirements?

Base


BASE LAYER
AESTHETIC LAYER
CONSTRUCTION LAYER
CUT OUTS FOR
IUFRA
LAYER
BOTTOM ATTACHMENT POINTS FOR FEET & CABLE MANAGEMENT
GRID OF HOLES
FOR BUILDINGBLOCK
MOUNTING

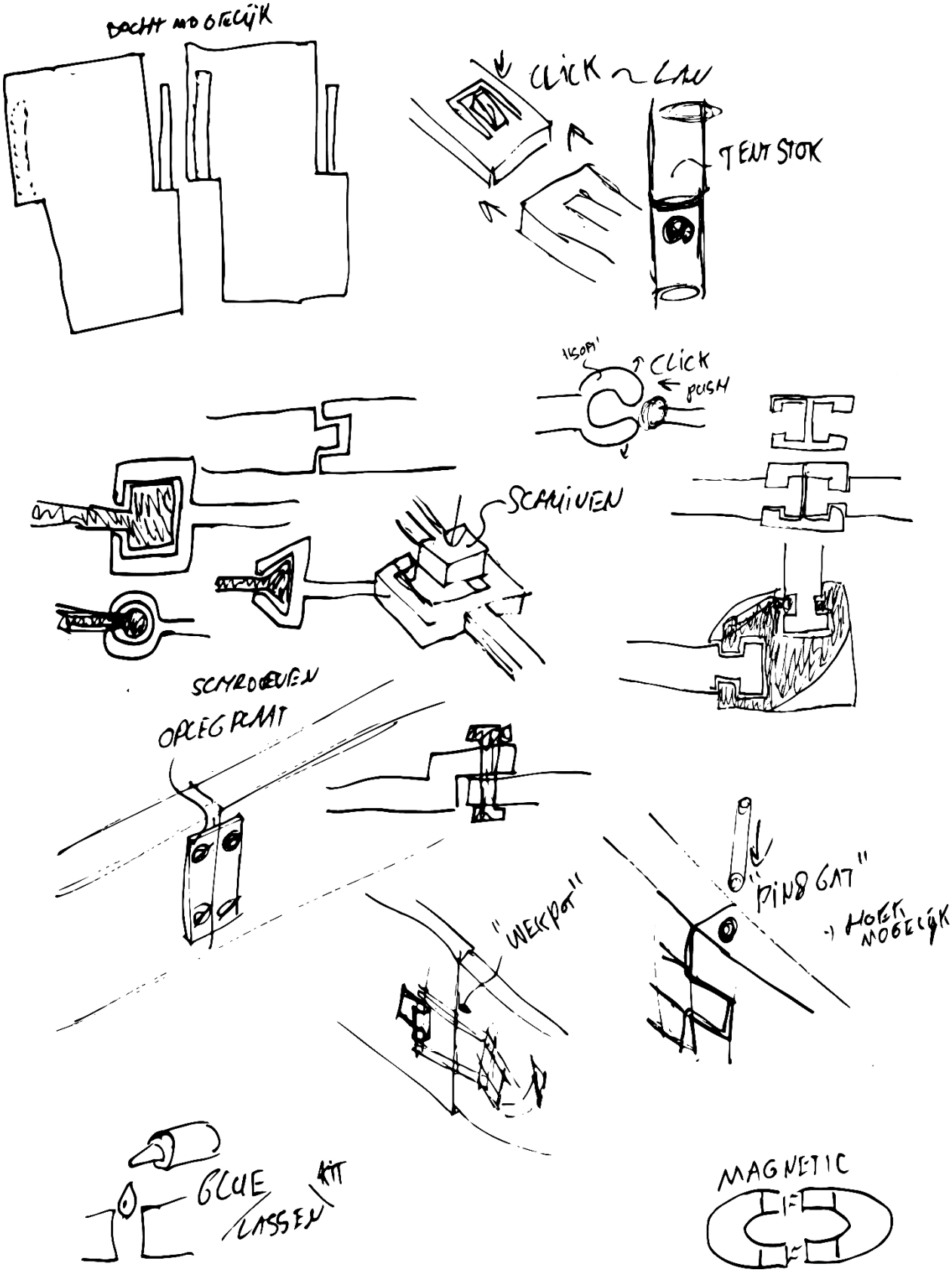
Building Blocks – Modules

The Building Block Layer is composed out of multiple individual modules. These modules house the Print Circuit Boards and other related electronic components. The modules should be flexible in use to accommodate the differing functions. This flexibility is applicable to the size of the modules, but also to the mounting options inside.



Size flexibility

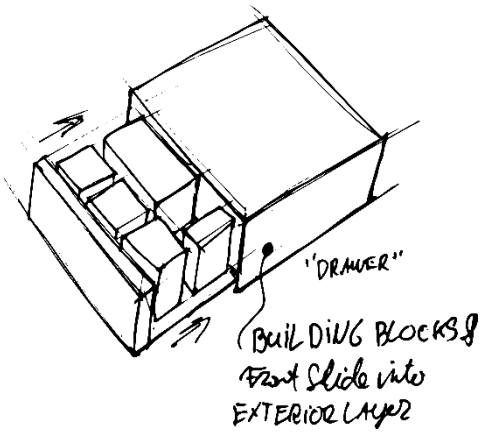
The dimensions of the Building Blocks are defined in Chapter X.X. A quick exploration of the possibilities of a modular enclosure is done.


DOPPE MOGELIJK
CLICK ~ CLAU
TENT STOK
ISOM
CLICK
PUSH
SCHROEVEN
SCHROEVEN
OPLEGPLAAT
"PING GAT"
HOEFT NIET MOGELIJK
"WEKPOT"
GLUE
KIT
LASSEN
MAGNETIC

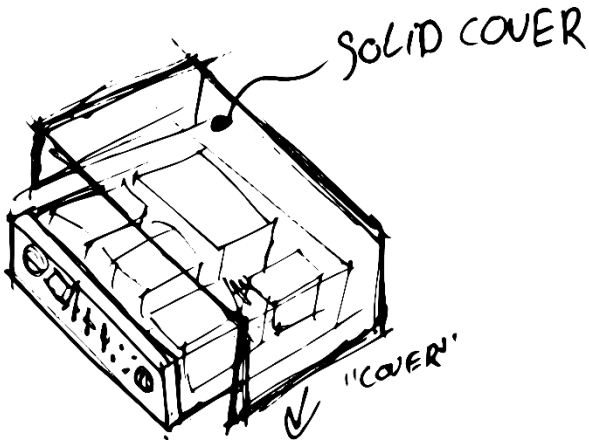
Exterior Layer Designs

Drawer

The drawer archetype protects the Building Blocks (BB's) by placing them inside a solid enclosure. The BB's can be reached by pulling the amplifier open, like a drawer. The BB's are mounted to the bottom of the drawer. The connectors, User Input and Feedback are located at the traditional locations.



Drawbacks: The Drawer Design has moving parts that wear and need a (complex) flexible cabling system. Opening the drawer moves the centre of gravity outside of the enclosure resulting in tipping over. This can be prevented by retractable wheels, but this only adds to the moving parts.



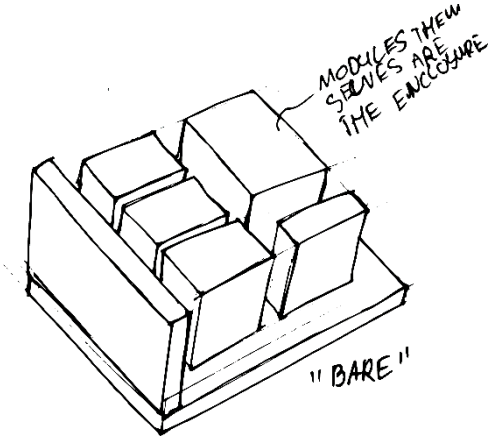
Traditional Solid

Traditional solid is, as the name suggest, not much different from current amplifier designs. The enclosure consists of two main parts, U shaped, fitting together to form a 'box'. The Connectors, User Input and Feedback are located at the traditional locations.

Drawbacks: As became clear in Chapter 3.2: Hotspot Mapping, opening and closing the enclosure takes a significant amount of time, reducing ease of use. The cover itself uses additional materials, without any significant benefits, since the modules themselves are already in an enclosure.

Bare

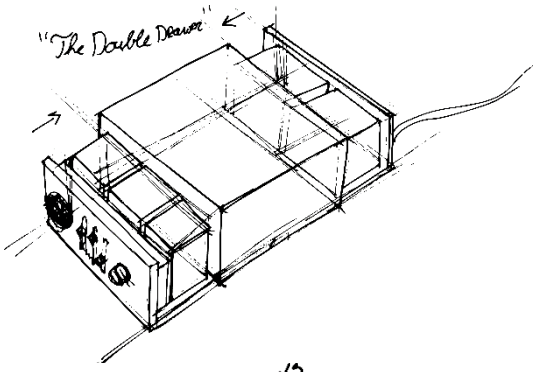
Bare shows its guts, the BB's are not covered by an external enclosure. Primarily the Building Blocks themselves are the enclosures, mounted to a common base. The User Input and Feedback are in the traditional location, the front. However, the connectors can be incorporated in the BB's or (partly) clustered at the back.



Drawbacks: The open structure, showing the individual BB's, might not be aesthetically pleasing to everyone. The cables need to be managed via module placement or another way.

Archetype variations

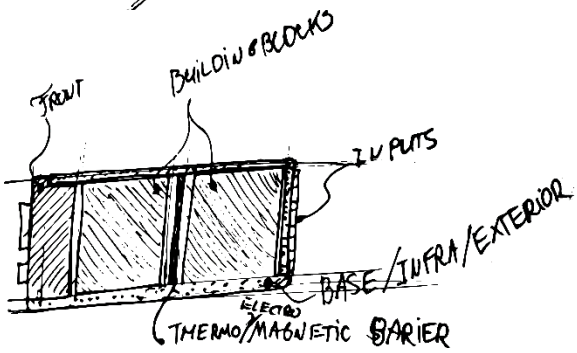
Based on the three described Exterior layer designs, variations are made. The variations can either increasing usability, ease of use or reduce the environmental impact.

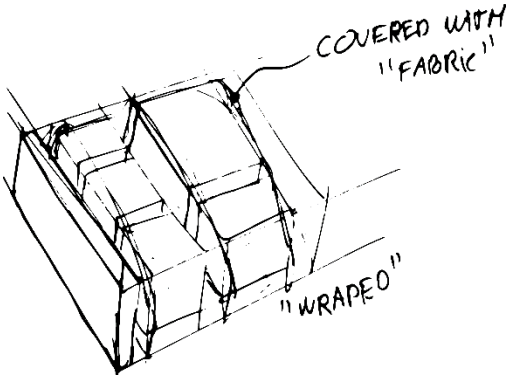


Double Drawer

The Double Drawer reduces the risk of tipping over while replacing or altering the layout of the IMS Concept. Cable management can also be improved, by arranging the modules according to their input and output connectors. An additional benefit is the space between the two drawers, this space can be used for thermal and/or magnetic barriers. The latter can improving sound quality, a thermal barrier can increase modules technical lifetime, as became clear in Chapter 3.2: Field research

Drawbacks: The number of moving parts has increased compared to the Drawer concept.





Fabric Flex

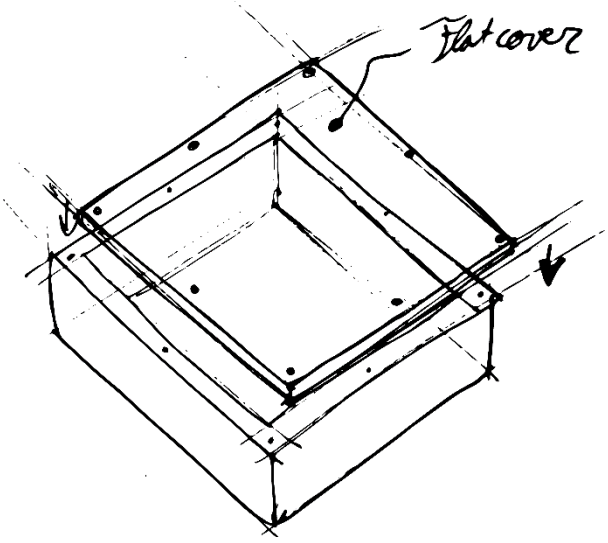
Fabric Flex is an alternative way to enclose the modules, resulting in a more traditional look of the IMS Concept. For the Fabric an environmentally friendly material can be selected, in different colours to match the users preferences.

Drawbacks: Fabric can be stained easily and is more difficult to clean than a hard surface. Does not prevent from external influences.

SolidCover

The SolidCover design consists of a solid base bucket and a solid cover. In the basket the different buildings blocks are placed, which are thereafter enclosed by the cover.

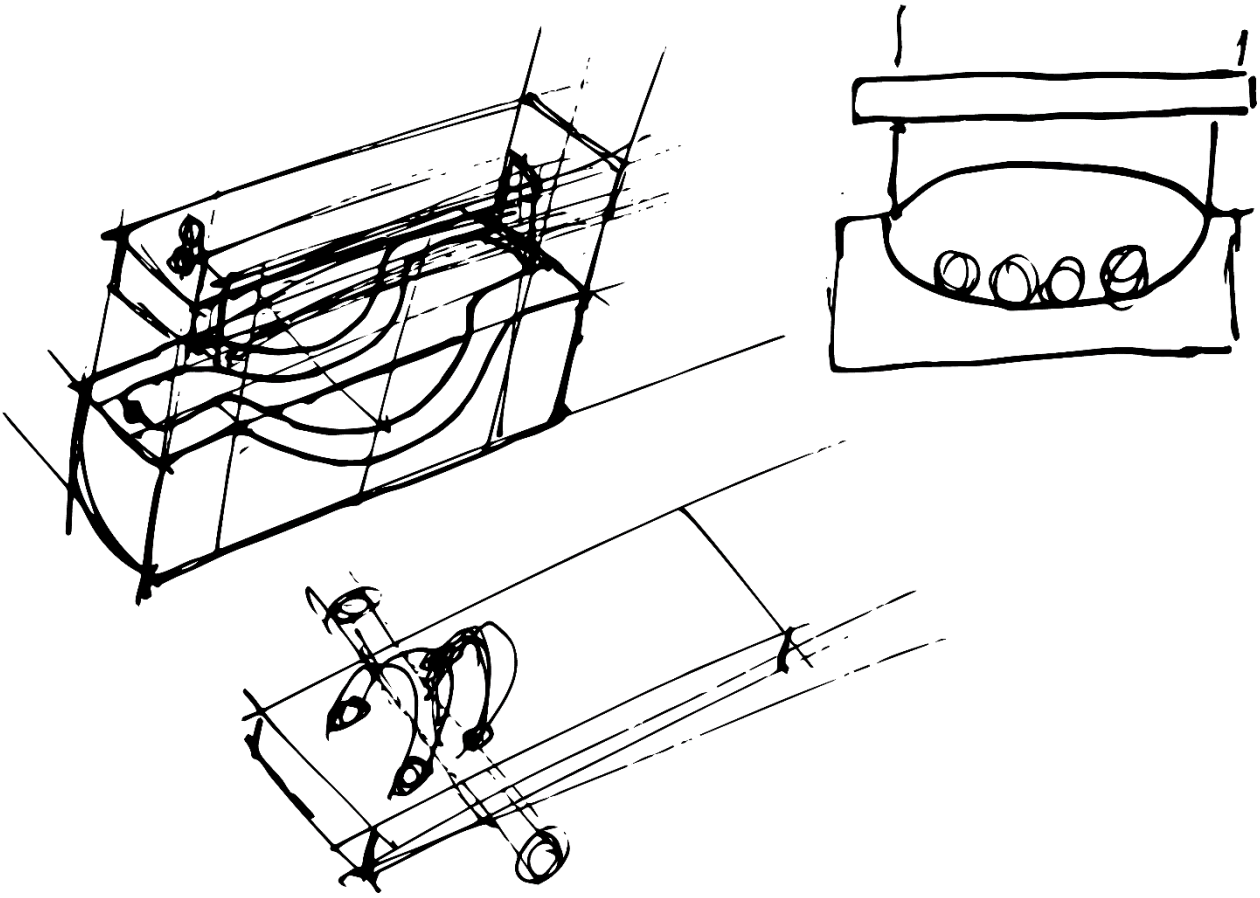
Drawbacks: the modules are double enclosed. The bucket needs a lot of material.



Exterior Layer selection

Changing the Building Blocks (BB's) is a key component of the IMS concept and should therefore be as easy as possible. By not having an additional layer to remove, or an enclosure to open up the Bare Exterior Layer concept has the most potential in this regard. Combined with the fact that it uses the least amount of material and has no moving parts the Bare Exterior layer is the starting point for the other design challenges.

Infrastructure Layer

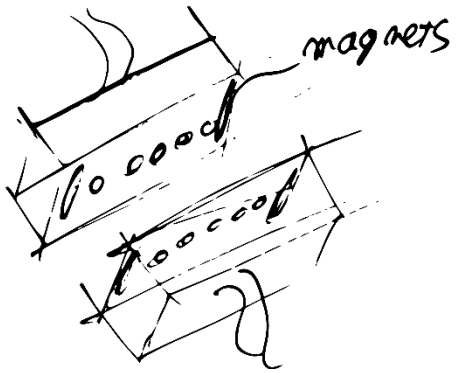


WRONG CONNECTION
EVENTION

CABLE CONNECTIONS

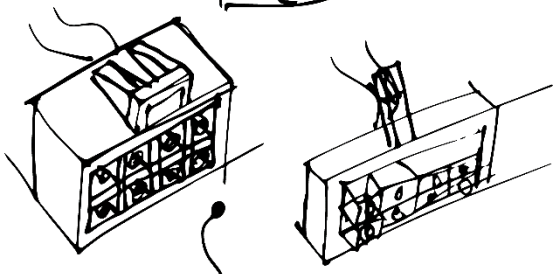
COLOR CODING INTERNAL

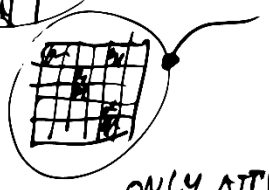
POWER = YELLOW
AUDIO = RED — INPUT / OUTPUT / DIGITAL
DATA = BLUE



POWER AUDIO DATA

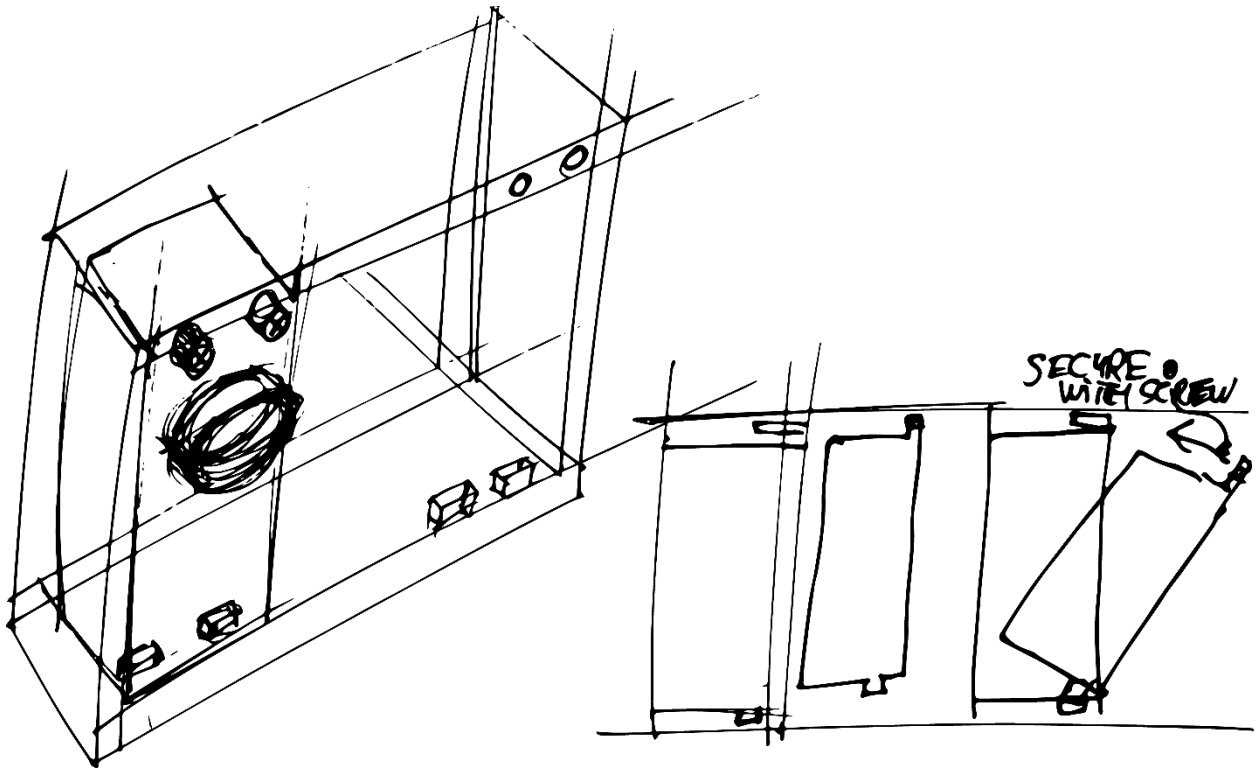
SPECIFIC SHAPE FOR EACH TYPE



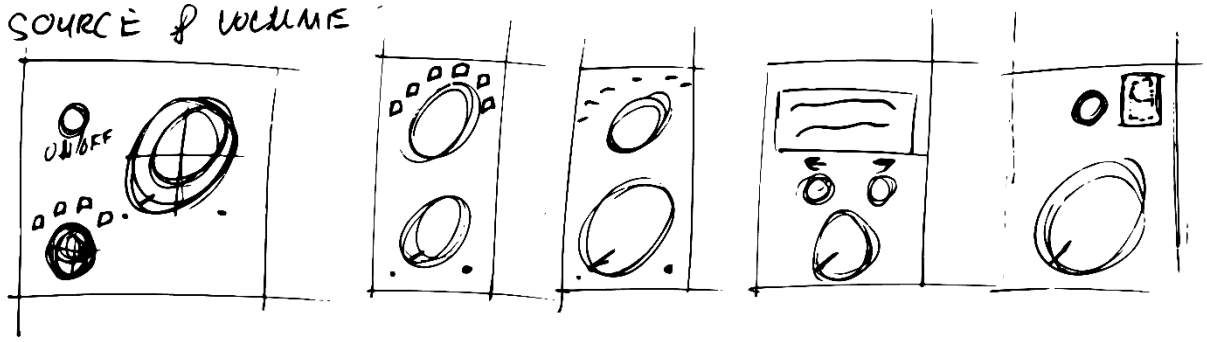


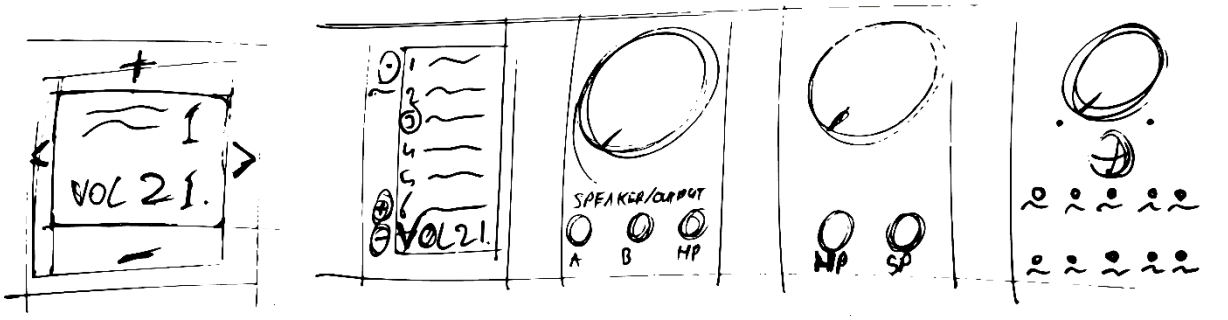
ONLY ATTRACTS IN 1 ORIENTATION

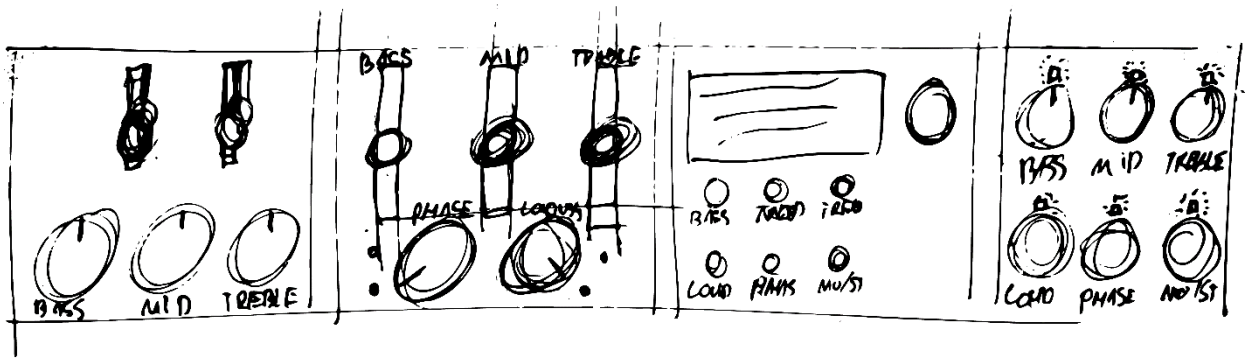
User Interface

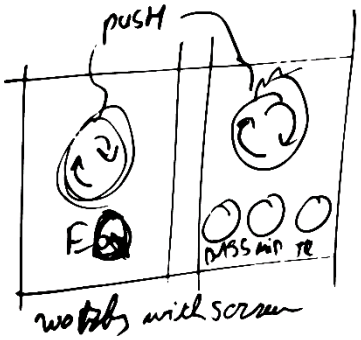


SOURCE & VOLUME









wobbly with screen

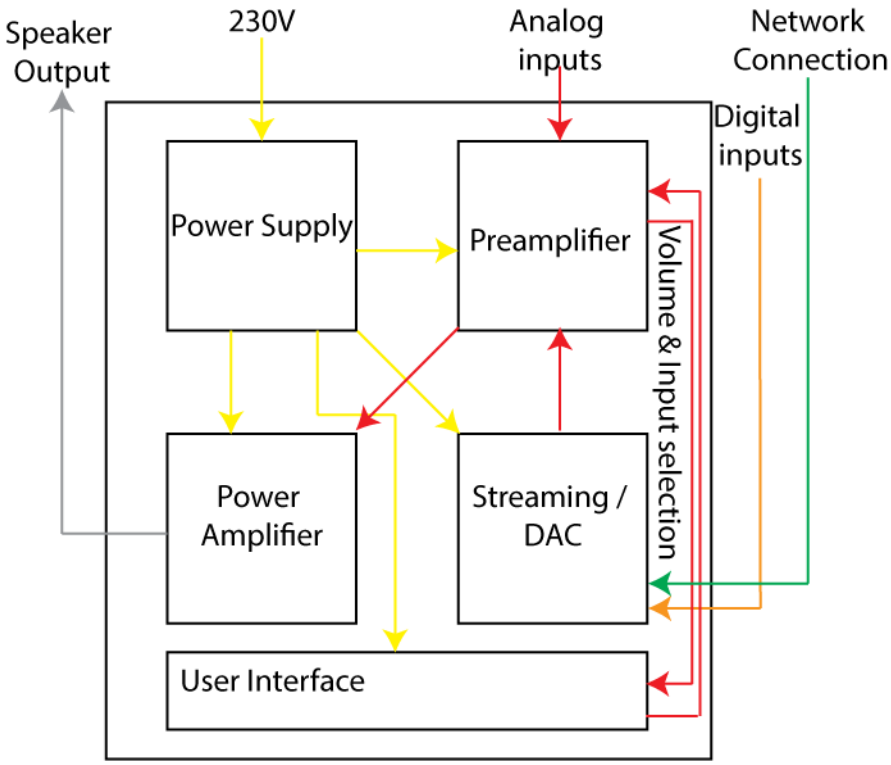
ANALOGUE : ROTATION (FREE/3 FREE)
: SLIDERS
: ANGLE?
: PUSH BUTTONS
: bends

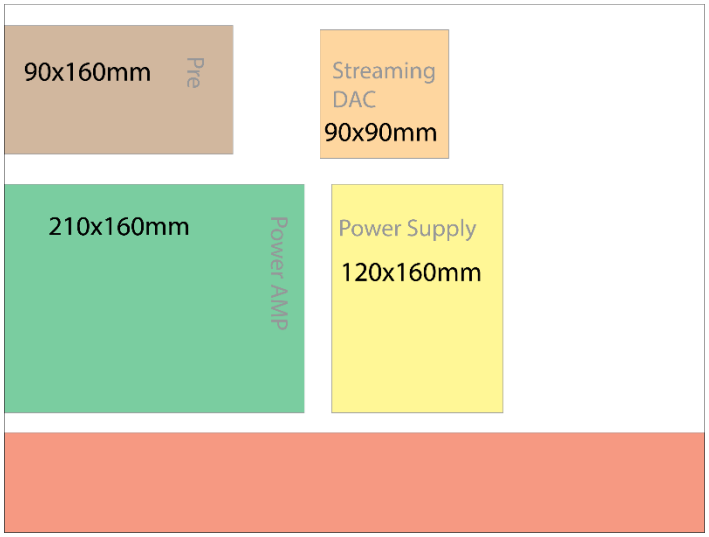
DIGITAL : Rotation + PUSH BUTTON
PLUS/minus button
APPLICATION

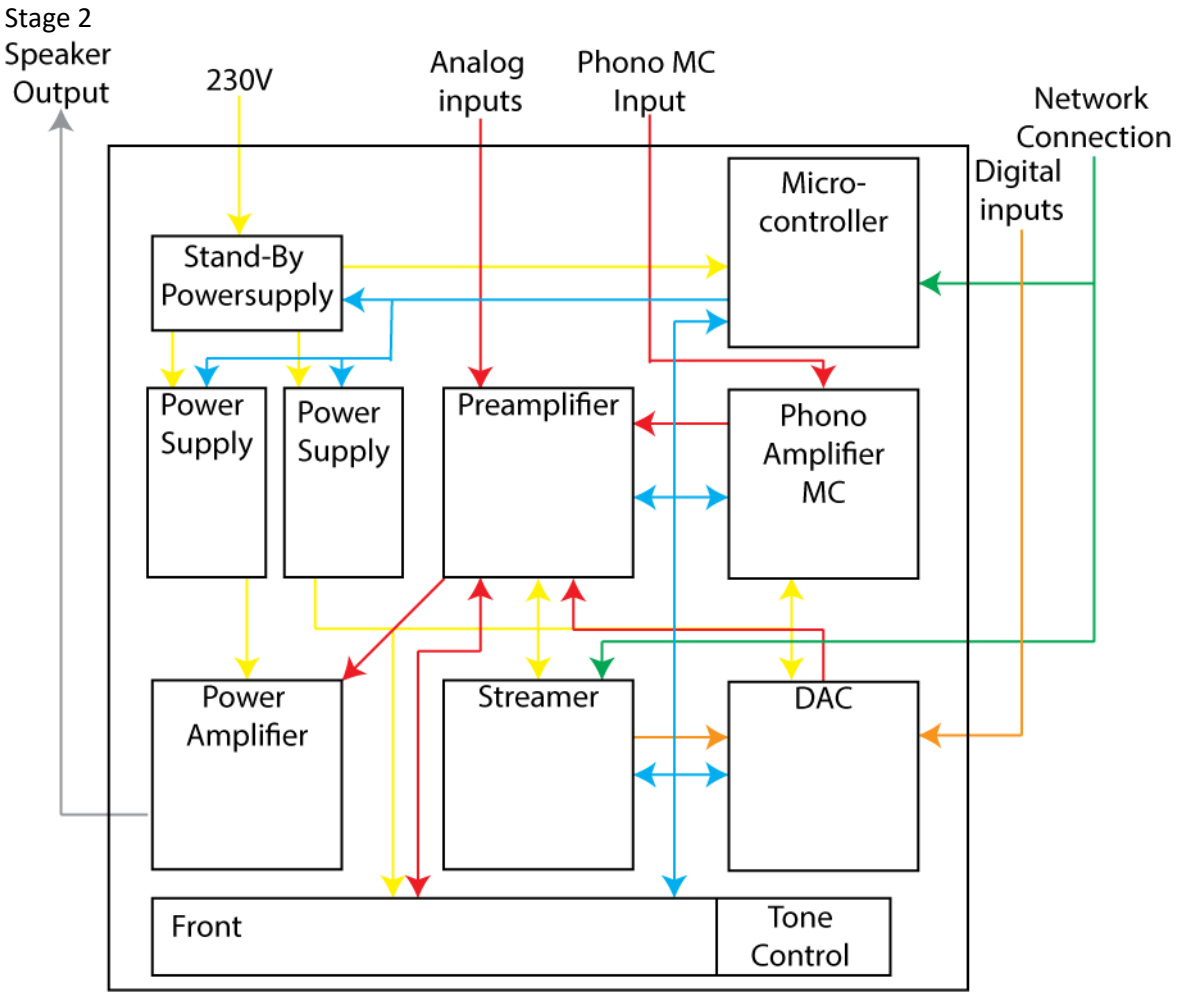
TONE CONTROL

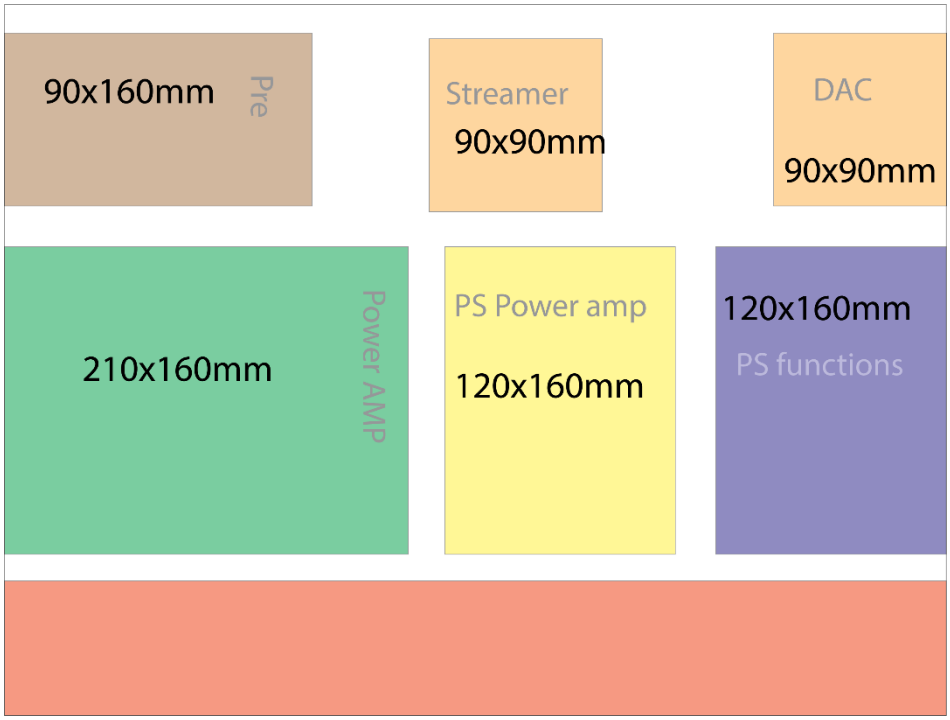
Appendix X – Stage compositions, infrastructure layer & Models

Stage 1

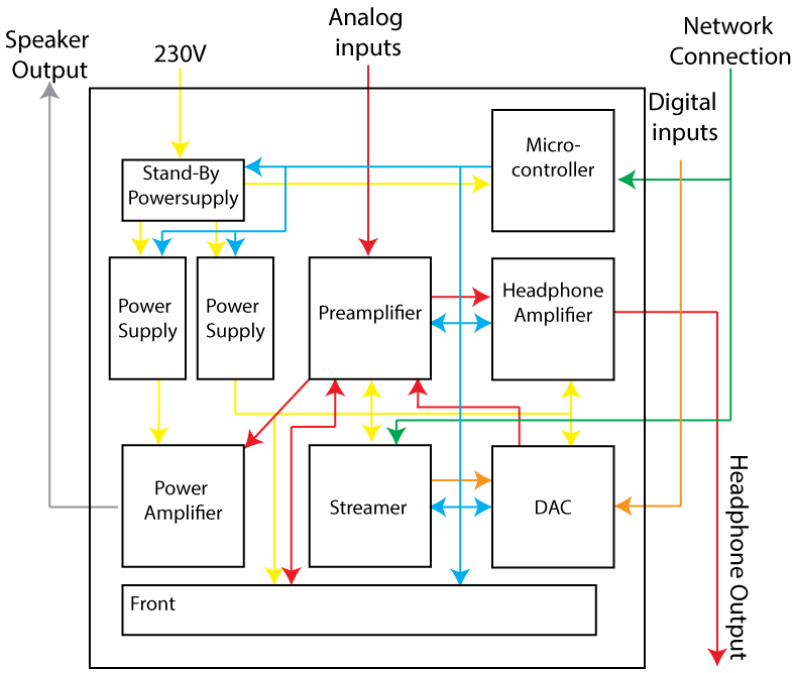




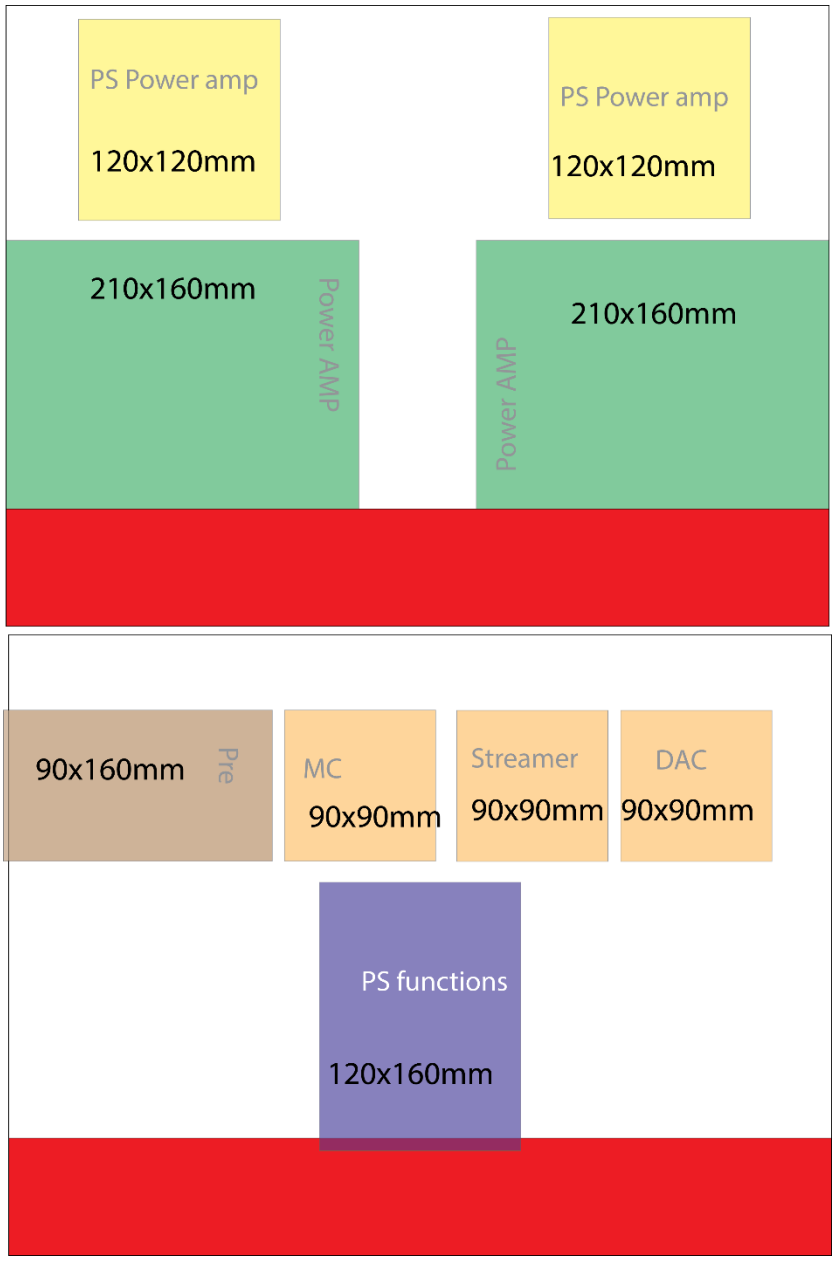

Stage 2
Speaker
Output
230V
Analog
inputs
Phono MC
Input
Network
Connection
Digital
inputs
Micro-
controller
Stand-By
Powersupply
Power
Supply
Power
Supply
Preamplifier
Phono
Amplifier
MC
Power
Amplifier
Streamer
DAC
Front
Tone
Control

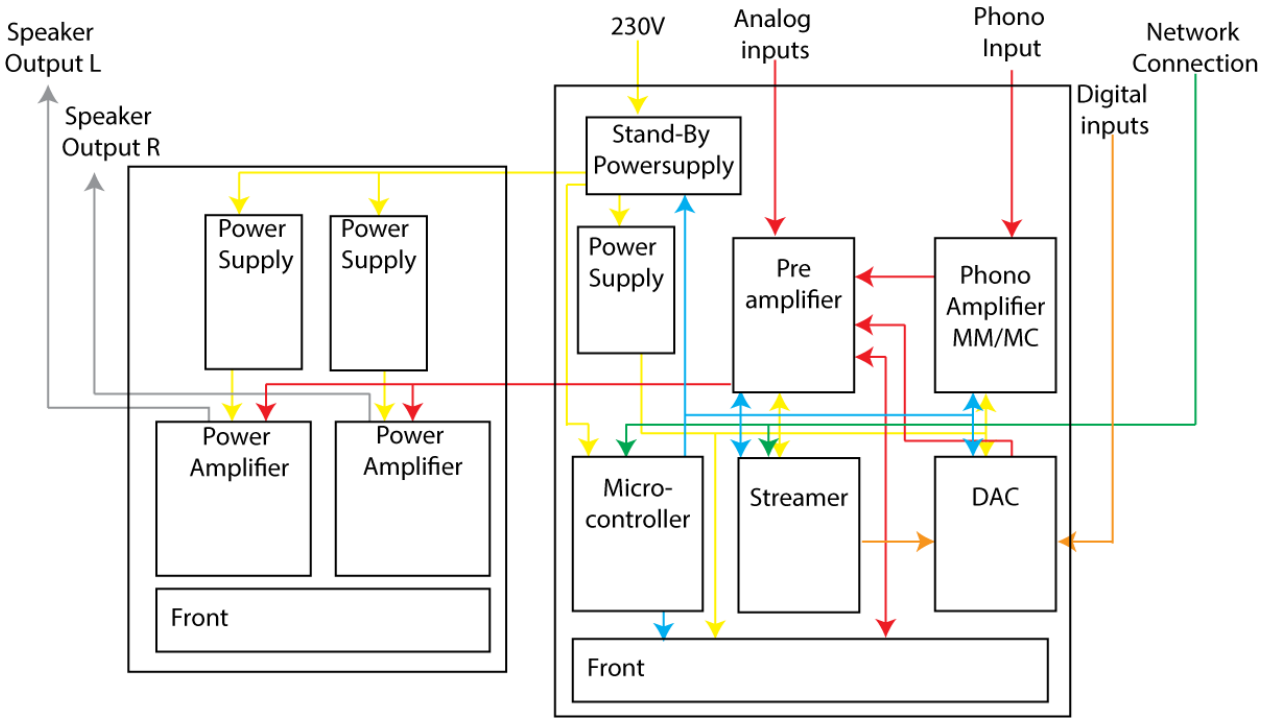

90x160mm
Pre
Streamer
90x90mm
DAC
90x90mm
210x160mm
Power AMP
PS Power amp
120x160mm
120x160mm
PS functions

Stage 3



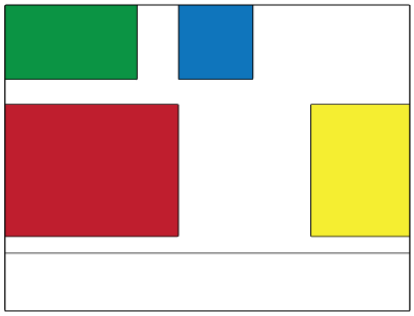
Stage 4

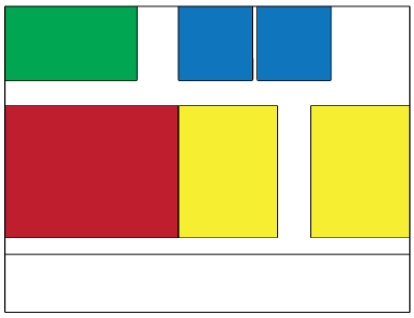

PS Power amp
120x120mm
PS Power amp
120x120mm
210x160mm
Power AMP
Power AMP
210x160mm
90x160mm
Pre
MC
90x90mm
Streamer
90x90mm
DAC
90x90mm
PS functions
120x160mm

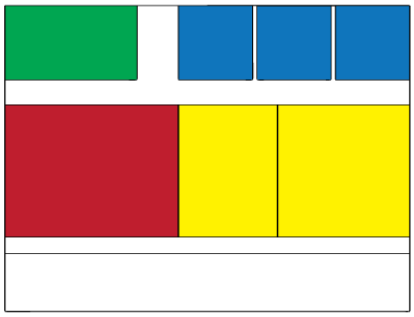

Speaker
Output L
Speaker
Output R
230V
Analog
inputs
Phono
Input
Network
Connection
Digital
inputs
Stand-By
Powersupply
Power
Supply
Power
Supply
Power
Supply
Pre
amplifier
Phono
Amplifier
MM/MC
Power
Amplifier
Power
Amplifier
Micro-
controller
Streamer
DAC
Front
Front

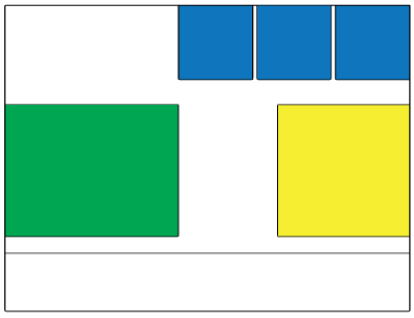
odel A & B

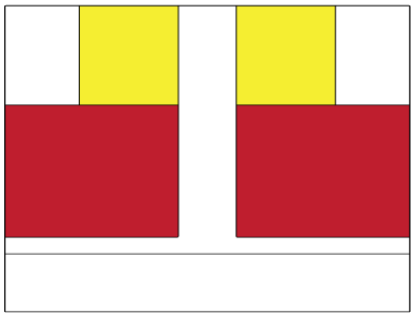
Model A



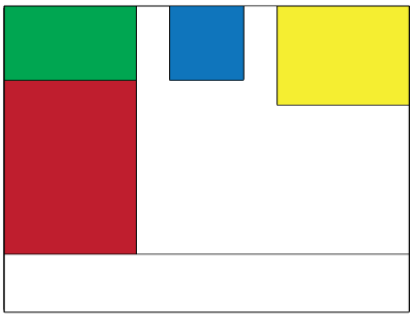


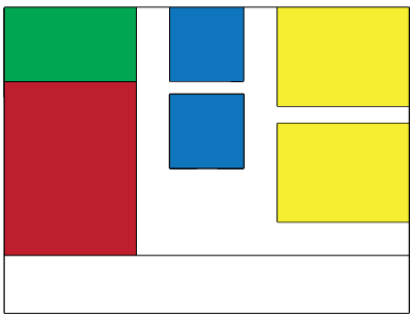


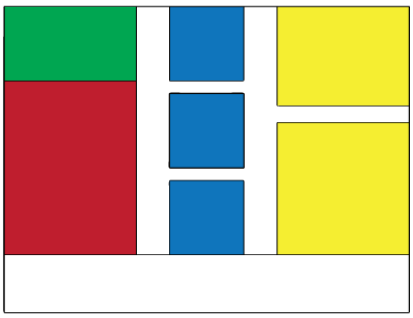


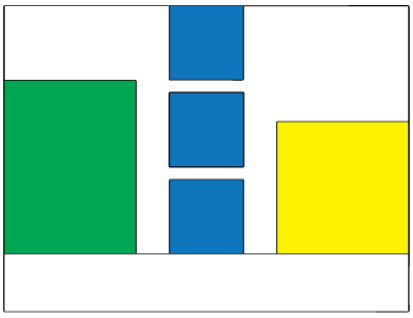


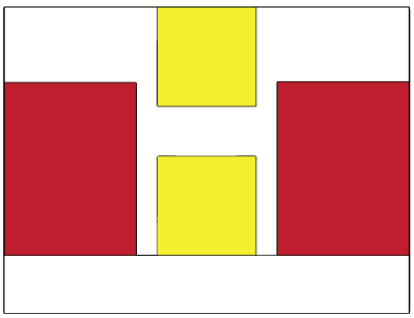
Model B



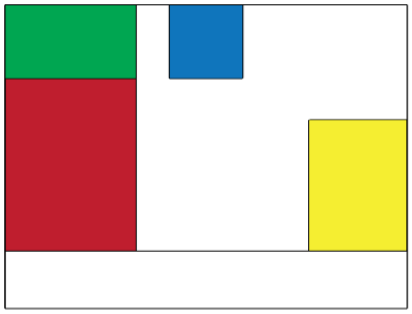


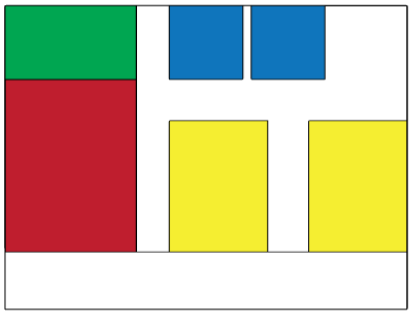


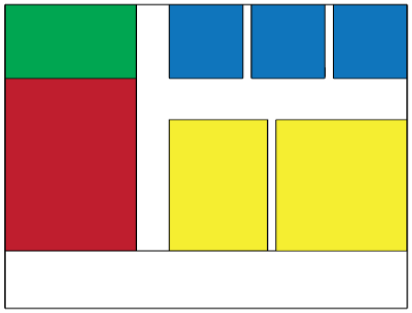


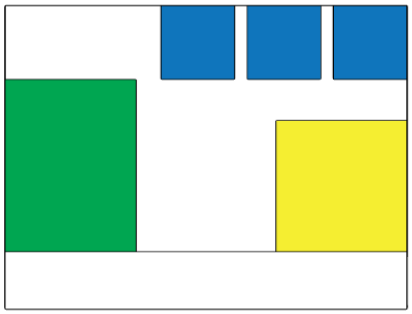


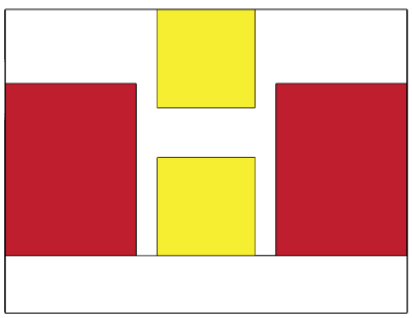
Model C



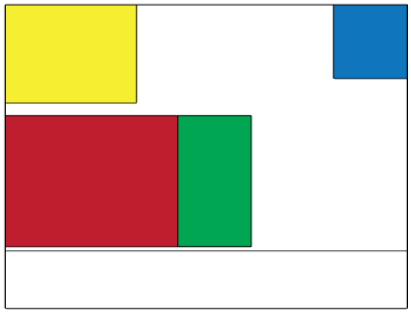


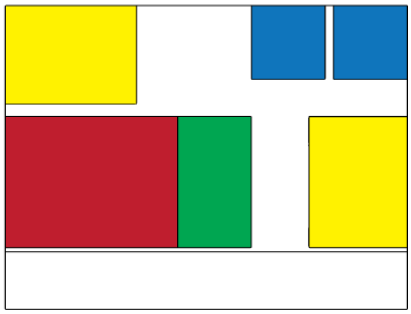


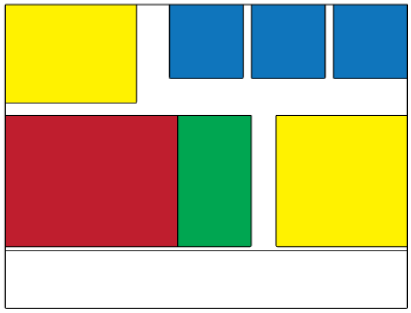


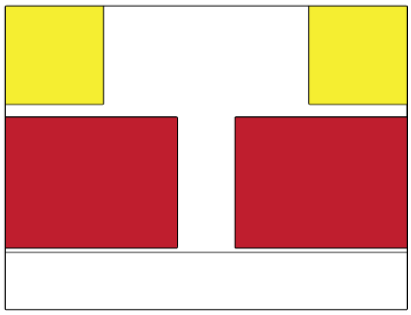


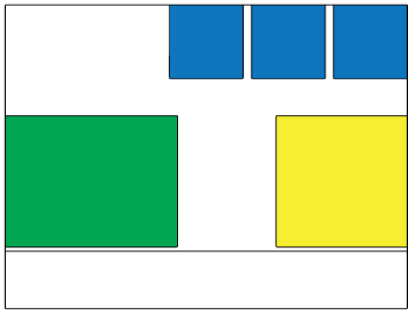
Model D











Appendix O – Aesthetic research Design & Results

Introduction

In the first part of the user research the usage, needs/wants and aesthetic preferences of Music Enthusiast, were investigated. It was observed that darker colours seem to be preferred over lighter colours.

In this new research the previous observation will be tested, are darker colours preferred. Furthermore, multiple possible lay-outs of the IMS concept are presented to the Music Enthusiasts to determine their preference. The designs are tested using the ranking method.

Research

The achieve the goal of this project, designing a sustainable HiFi solution, the system needs to be used for as long as possible by one user. During use the system will expand and grow to meet the users requirements and wishes. In this user research the different stages, configurations, will be presented, if not combined with colour combinations.

Research Question

Which IMS concept lay-out and colour are preferred by Music Enthusiast

Sub Questions

- What is the preferred stage within the models
- What is the preferred model within the stages
- What is the preferred colour (combination)

Participants

The previously mentioned Music Enthusiasts are customers of Audiohuis Delft. They can either be a Music Enthusiast themselves, or live with a Music Enthusiast. During the first part of the research personal information was gathered, of those who indicated to be willing to participate in future research. Those participants will be the customer panel used for this part of the research. If the number of respondents is insufficient, 'new' customers of Audiohuis Delft might be asked to participate.

There are no characteristics specific to a Music Enthusiast, with regards to gender, age, etc…

Stimuli

As stimuli computer generated images are used, renders made using KeyShot of a SolidWorks CAD file. The renders are made using a fixed camera viewpoint and lighting conditions. In figure 1 an overview of the four different models and their associated stages can be seen. In figure 2 the nine different colour (combinations) can be seen. The colours applied to Model A, stage 3, visualised in figure 2 are also applied to all other models and stages.

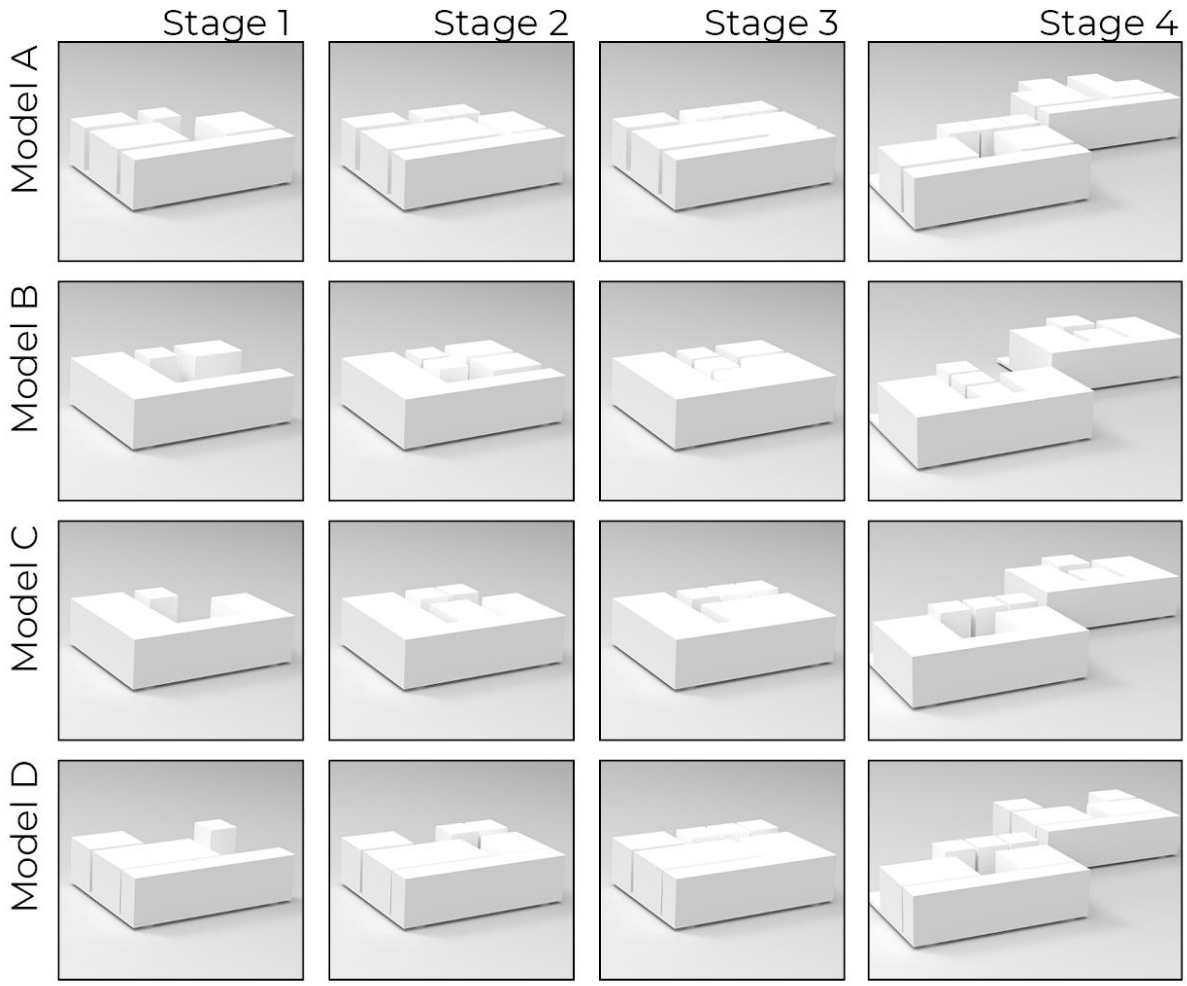


Figure 1: Four models (vertical), Four stages (Horizontal).

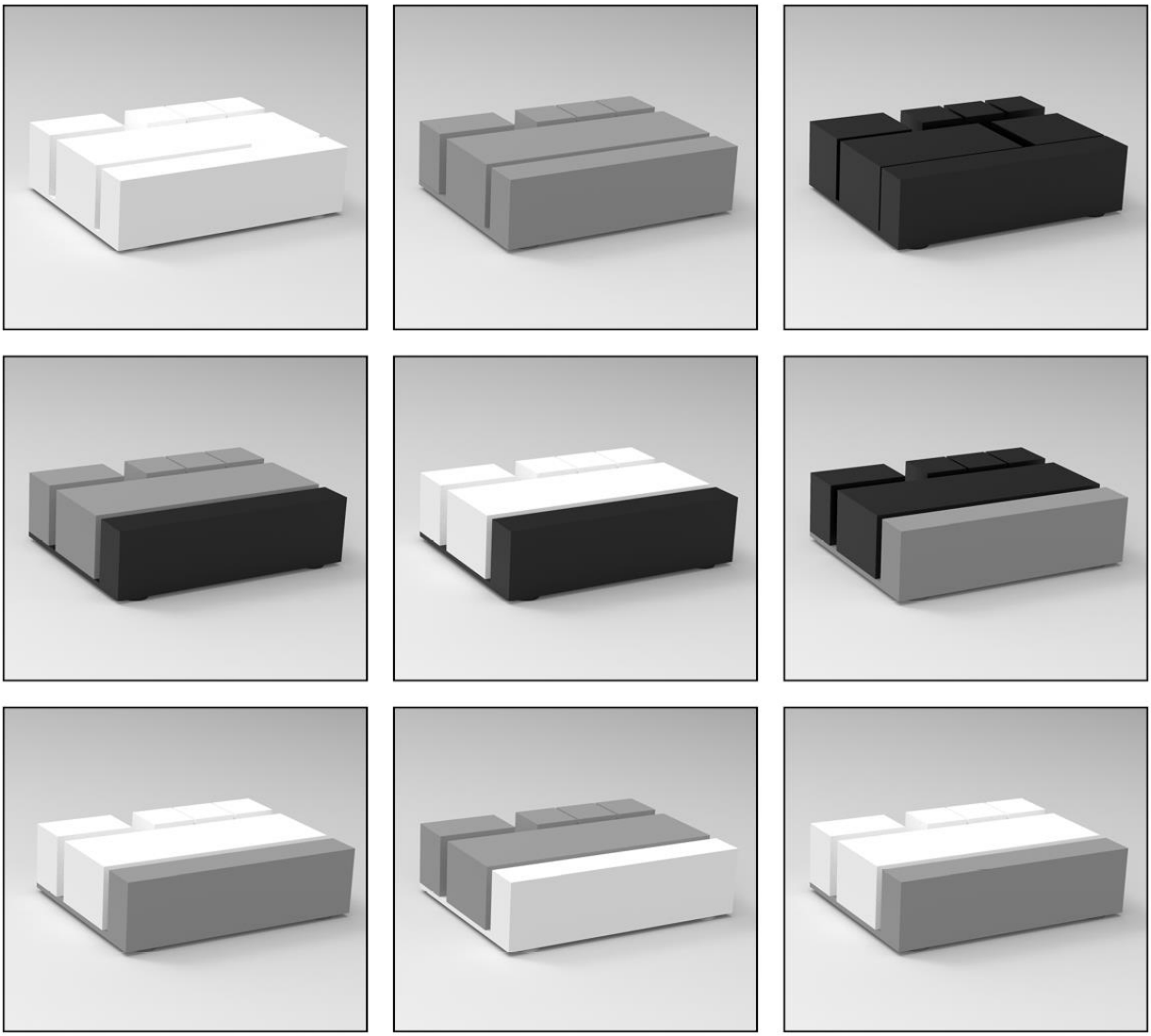


Figure 2: Colours and colour combinations researched. (Model A, stage 3)

Apparatus

The research is conducted in the form of an online questionnaire. The questionnaire is made using Google Forms for easy distribution. The research invitation has been send to the ten customer, in the customer panel, via personalised emails.

The research can be completed on a personal device of the participant. It could be completed on a mobile phone. However, at the beginning of the research it is mentioned that a tablet or personal computer is better suited, due to its bigger screen..

Procedure

The customer panel received the research invitation on their personal email. The email and research are both completely in Dutch, since there are no native English speakers in the customer panel. The online questionnaire, as it was sent to them, can be seen in Appendix X.

The research starts with a recap of the previous research, what the goal was and what was achieved. Following the new research is introduced, combined with the desired goal. The part of the questionnaire that gathered new data is divided into four sections:

- Preference of stage within the four models
- Preference of the stages, between the four models
- Preference of colour
- Preference of colour and lay-out

At the end of the questionnaire the participants have the option to leave additional information and remarks. Finally they are thanked for their participation and invited to, yet again, partake in future research.

Measure

- Ranking vs Pairwise Comparison vs Conjoint Analysis
  - Ranking selected, due to less questions than with Pairwise comparison
  - Conjoint could achieve the same results, with less questions, but is to advanced for the different parameters researched. Better suited if more attributes would be tested at once.
- Semantic Differential Scale – 4 6 or 9 steps
- Results analysed using SPSS
- One way within ANOVA (Friedmans ANOVA / Kendall's W test)
  Middels een Friedman Test worden verschillen tussen groepen gemeten, wanneer de afhankelijke variabele van ordinal meetniveau is. De Friedman Test is beschikbaar via: Analyze > Nonparametric tests > Legacy Dialogs > K Related Samples.

  - H0: The stages within a model are all equally ranked
  - H0: The models within a stage are all equally ranked
  - H0: The colours are all equally ranked / H0: Dark colours are preferred

Results

	Model A*	rank	Model B	rank	Model C*	rank	Model D*	rank
Most preferred	Stage 2	1,78	Stage 2	1,78	Stage 2	1,56	Stage 2	1,78
	Stage 3	2,22	Stage 3	2,22	Stage 3	2,11	Stage 3	1,78
	Stage 1	2,44	Stage 1	2,67	Stage 1	2,44	Stage 1	2,89
Least preferred	Stage 4	3,56	Stage 4	3,33	Stage 4	3,89	Stage 4	3,56

* results appear to be statistically significant at p=0.05 level

Voor elk modeltype geldt dezelfde volgorde aan stagevoorkeuren. Stage 2, een versterker met 6 modules, verdient in elk model de voorkeur. Stage 4, een variant die uit twee versterkers bestaat, wordt opvallend vaak als minst aantrekkelijke optie beschouwd. Voor Model D geldt dat er geen voorkeur is voor stage 2 en 3.

There was a statistically significant difference in the preference of a stage for Model A, Model C and Model D, which implies that not every stage is preferred equally.

	Stage 1	rank	Stage 2	rank	Stage 3*	rank	Stage 4	rank
Most preferred	Model B	1,56	Model B	1,78	Model A	1,67	Model B	2,22
	Model A	2,67	Model A	2,33	Model B	1,89	Model A	2,33
	Model D	2,83	Model D	2,78	Model D	3,00	Model C	2,67
Least preferred	Model C	2,94	Model C	3,11	Model C	3,44	Model D	2,78

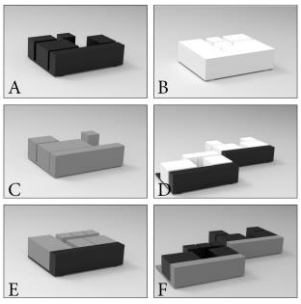
* results appear to be statistically significant at p=0.05 level

Voor de stages is eveneens een patroon te herkennen in de modellen die als mooist worden ervaren. Overall is Model B de voorkeursoptie, gevolgd door Model A, D en C. Voor een versterker met 7 modules, stage 3, is de voorkeur voor Model A groter dan Model B, hoewelhet verschil klein is. Ook intressant is dat voor Stage 4 de voorkeursverrschillen tussen de verschillende modellen niet erg uitgesproken is, gezien de rankingwaarden erg dicht bij elkaar liggen. Voor Stage 1 en 2 is de voorkeur voor model B ten opzichte van alle andere modellen wel aanwezig.

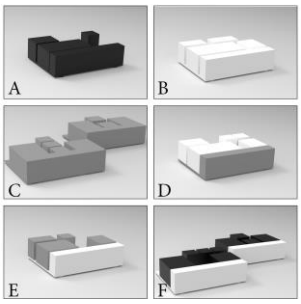
In the ranking based on stages only Stage 3 appears to be statistical significant. For Stage 3 it can be concluded with certainty that there is a difference in the preference of Model types. For the other stages *geldt dat het in de steekproef gemeten verschil niet zondermeer algemeen van toepassing is. Echter, omdat de modelvoorkeuren per stage aardig overeen komen, is het alsnog aannemelijk te verwachten dat Model B de voorkeur geniet boven andere modeltypes.*

Er zit een verschil in het aantal significante resultaten.Voor Stage als afhankelijke variabele geldt dat er drie resultaten significant zijn, terwijl voor Model als afhankelijke variabele slechts één resultaat significant is. Hieruit kan opgemaakt worden dat de verzamelde resultaten met betrekking tot stagevoorkeuren meer eenduidig is. Om een significant resultaat voor modelvoorkeuren te kunnen bereiken zou de enquete door meer respondenten ingevuld moeten worden.

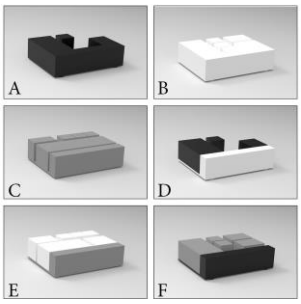
Voorkeuren – kleur, model, stage



Ranking 1



Ranking 2



Ranking 3

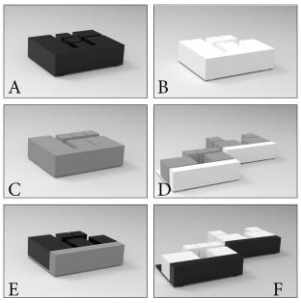
	Ranking 1*	rank	**Ranking 2**	rank	**Ranking 3**	rank
Most preferred	A1, Black	2,78	A2, White	3,00	B2, Black & Grey	2,33
	D4, Grey & Black	2,89	A1, White & Grey	3,11	A3, Grey	3,11
	D1, Grey	3,11	D1, Black	3,22	D3, Grey & White	3,11
	C3, Black & Grey	3,33	D2, Grey & White	3,22	B3, White	3,78
	B3, White	3,56	B4, Grey	3,56	C1, Black	3,89
Least preferred	A4, Black & White	5,33	C4, White & Black	4,89	C1, White & Black	4,78

* Ranking 1 appears to be statistically significant at p=0.05 level

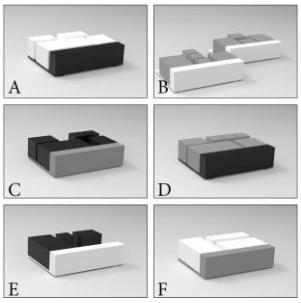
For Ranking 1, biggest consensus about D1 Grey, standard deviation of 0,782 and smallest consensus about B3 White, which has a standard deviation of 2,242.

For Ranking 2, biggest consensus about D2, Grey & White, standard deviation of 1,093 and smallest consensus about A1, Grey, which had a standard deviation of 2,088.

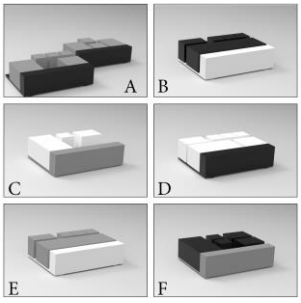
For Ranking 3, biggest consensus about A3, Grey, standard deviation of 1,167 and smallest consensus about B3, White, which had a standard deviation of 2,167.



Ranking 4



Ranking 5



Ranking 6

	Ranking 4	rank	**Ranking 5**	rank	**Ranking 6**	rank
Most preferred	B3, Black	2,44	D3, Black & Grey	2,22	B2, Grey & Black	2,11
	C2, Grey & Black	2,67	C3, Grey & White	3,00	A3, White & Grey	2,56
	C3, Grey	3,33	D2, Grey & Black	3,22	A3, White & Black	3,89

	A4, White & Grey	3,78	B4, White & Grey	3,78	B1, Grey & White	4,11
	C2, White	4,33	A2, Black & White	4,22	C4, Black & Grey	4,11
Least preferred	D4, Black & White	4,44	B1, White & Black	4,44	D3, Black & White	4,22

* No results appear to be statistically significant at p=0.05 level

For Ranking 4, biggest consensus about C3 Grey, standard deviation of 1,000 and smallest consensus about B3 Black, which has a standard deviation of 2,128.

For Ranking 5, biggest consensus about D3 Black & Grey, standard deviation of 1,302 and smallest consensus about C3 Grey & White, which has a standard deviation of 1,936.

For Ranking 6, biggest consensus about A3 White & Grey, standard deviation of 1,236 and smallest consensus about C4 Black & Grey, which has a standard deviation of 2,028.

	Ranking 7	rank	**Ranking 8***	rank	**Ranking 9***	rank	**Ranking 10**	rank
Most preferred	C3, Black	3,56	A3, Grey & Black	3,11	A3, Grey	2,89	C3, Grey & Black	3,44
	B3, Black & Grey	3,56	B3, Black	3,89	D3, Black	3,56	B4, Black & Grey	4,44
	A1, Grey	3,78	A2, Grey & White	4,00	B2, Grey & Black	4,44	D1, Black	4,56
	D1, Grey & Black	4,78	D3, Grey	4,33	A4, Black & Grey	4,89	A4, Grey & White	5,00
	A2, White & Black	5,33	B1, Black & Grey	5,00	C2, White & Black	5,11	C2, Black & White	5,11
	A4, Grey & White	5,56	B4, White & Grey	5,22	A4, Black & Grey	5,11	B3, White & Black	5,33
	D2, Black & White	5,78	D2, White & Black	5,67	C2, White & Grey	5,11	B4, White & Grey	5,56
	B4, White	6,00	C4, Black & White	6,67	D4, White	6,89	D1, Grey	5,78
Least preferred	C4, White & Grey	6,67	C1, White	7,11	C1, Black & White	7,00	A1, White	5,78

* Ranking 8 and Ranking 9 appear to be statistically significant at p=0.05 level

For Ranking 7, biggest consensus about D2 Black& White, standard deviation of 1,394 and smallest consensus about D1 Grey & Black, which has a standard deviation of 3,114.

For Ranking 8, biggest consensus about A2, Grey & White, standard deviation of 1,803 and smallest consensus about B3 Black, which has a standard deviation of 3,108.

For Ranking 9, biggest consensus about A3 Grey, standard deviation of 1,269 and smallest consensus about D3 Black, which has a standard deviation of 3,321.

For Ranking 10, biggest consensus about B4 White & Grey, standard deviation of 2,007 and smallest consensus about C3 Grey & Black, which has a standard deviation of 3,167.

Stage 1*	rank	**Stage 2***	rank	**Stage 3**	rank	**Stage4**	Rank
A, Black	3,28	B, Grey & Black	3,00	D, Black & Grey	4,22	D, Grey & Black	2,89

Most preferred	D, Grey	3,28	B, Black & Grey	3,28	B, Black	4,78	B, Grey	3,56
	A, White & Grey	3,78	C, Grey & Black	3,72	A, White & Grey	5,17	A, White & Grey	3,94
	D, Grey	3,89	A, White	4,17	C, Grey & White	6,11	B, White & Grey	4,11
	C, Black	4,78	D, Grey &White	4,28	A, Grey	6,28	C, Black & Grey	4,78
	B, Grey & White	5,06	D, Grey & Black	4,83	D, Grey & White	6,61	D, Black & White	4,83
	B, White & Black	5,67	C, White	6,33	C, Grey	6,78	C, White & Black	5,56
	C, White & Black	6,28	A, Black & White	6,39	C, Black & Grey	6,78	A, Black & White	6,33
					B, White	7,11		
					B, White	7,22		
					A, White & Black	8,17		
Least preferred					D, Black & White	8,78		

There seems to be no pattern in models that are preferred within esthetical preferences. However, the aspect of colour is very clear in this overview. Black & White combinations are valued low. On the other hand, the colour combination Black & Grey works well.

	Model A*	rank	**Model B**	rank	**Model C**	rank	**Model D**	Rank
Most preferred	S3, White & Grey	3,39	S2, Grey & Black	3,50	S2, Grey & Black	3,28	S3, Black & Grey	3,11
	S1, Black	3,83	S2, Black & Grey	3,78	S3, Grey & White	3,78	S4, Grey & Black	4,33
	S3, Grey	4,17	S3, Black	3,89	S3, Grey	4,22	S3, Grey & White	4,56
	S1, White & Grey	4,17	S4, Grey	5,17	S3, Black & Grey	4,28	S1, Black	4,72
	S2, White	4,44	S3, White	5,17	S1, Black	4,83	S2, Grey & White	4,83
	S4, White & Grey	5,28	S3, White	5,39	S4, Black & Grey	5,44	S1, Grey	5,00
	S3, White& Black	5,67	S4, White & Grey	5,78	S2, White	5,72	S2, Grey & Black	5,17
	S2, Black & White	6,28	S1, Grey & White	5,89	S1, White & Black	6,67	S3, Black & White	6,44
Least preferred	S4, Black & White	7,78	S1, White& Black	6,44	S4, White & Black	6,78	S4, Black & White	6,83

Based on stages, a small preferences for stage 2 and 3 can be differentiated based on above results. In this overviews colour also plays an important role.

Esthetical preferences seems to be based on: 1. Colour, 2. Stage, 3.Model.

Let op, niet statistisch bewezen, slechts een indicatie op basis van bovenstaande tabellen. Slechts een aanname van een patroon na beschouwing van bovenstaande tabellen. Voor daarwerkelijke uitluiting zou een onderzoekop basis van conjuncte analyse uitgevoerd moeten worden.

Discussion

Image generation

During the setup phase of the research the images that would be used in the different sections of the questionnaire were made. The way these images are made can be improved.

Section 1 & 2

In the first two sections these images are grouped per model or per stage, in a 2x2 grid. However the location of the image of each model/stage is constantly the same, which could result in a pattern. It would have been better to put each image in a random location, within the 2x2 grid.

Section 3

Section 3 introduced the different colours and colour combinations, nine in total. The solid colours were only used in four of the six images. It would have been better to distribute the solid colours and colour combinations evenly.

Section 4

In section 4 the participants were presented with 4 images, each containing 9 figures of the different models in different colours. The model and colours are chosen as random as a human is capable of. However it would have been better to let software make the matches to remove human bias. This also applies to the colour matching in section 3.

Overall

The preferences of the participants is only researched using ranking questions, choosing one over another. However, in the current setup an equal preference is not possible.
The ranking method is selected, due to the fact that only a small sample size is available, and ranking is then preferred.
Furthermore, it would have been better to verify the gathered data using another question type, for example grading. Give each design a grade between 1 and 10.
For the questions regarding colour scoring would have been the better option, now there are no significant statistical conclusions to be drawn, other than that Black and White are always scored the lowest.

Stage 4, variant D is consists of 2 separate bases, this was not clear to the research participants.

On the questions were 6 images were ranked no difficulties were experienced. However there were also questions with 9 images, these were difficult, and is ‘complained’ about. .

A full pilot study, including all statistical analysis should have been conducted. Not only a pilot test whether the questionnaire itself was understandable.

Future research/suggestions

- Use Conjoint analysis when more attributes are known and/or ready for testing, for example;
    - Technical lifetime, Definitive colour options, Material, Costs, Level of performance

“Conjoint Analysis; suited for multi factor analysis, with multiple variables within each factor. Gives researches data regarding the importance of certain aspects of design, is price more influential, or color, for example. “

Esthetics User Test

(Deelname op een mobiele telefoon is mogelijk, maar een tablet of computer is meer geschikt)

Geachte muziekliefhebber,

Welkom terug bij het onderzoek naar een modulair versterker concept. In het eerste deel werd u om uw voorkeuren gevraagd, met betrekking tot functies, esthetische voorkeuren en gebruik.

In dit vervolg onderzoek wordt verder ingegaan op uw esthetische voorkeuren, maar dan niet met betrekking tot huidige modellen, maar tot het nieuwe concept. Het nieuwe concept; IMS, Integrated Music Solutions, heeft als doel om levenslang mee te gaan. Om dit te bereiken moet IMS systems met u mee kunnen groeien, zodat in elk stadium aan uw eisen en wensen kan worden voldaan. Om dit mogelijk te maken zijn er vier (4) ontwerpen gemaakt, waarvan de indeling verschilt, maar het hoofdontwerp gelijk blijft. Daarnaast wordt er gebruik gemaakt van een drietal kleuren die, gecombineerd, 9 combinaties opleveren.

Tijdens de komende vragen mag u wederom uw mening geven omtrent de gepresenteerde ontwerpen. U krijgt telkens 4 tot 9 afbeeldingen gepresenteerd, welke u naar uw esthetische voorkeur mag rangschikken. Het onderzoek bestaat uit 4 secties, wat u bij deelname, ongeveer 10 minuten zal kosten.

De uitkomsten van deze enquête zullen worden gebruikt voor wetenschappelijk onderzoek vanuit de TU Delft naar de toepassing van een modulair ontwerp op een geïntegreerde versterker. U deelname is geheel vrijblijvend en u mag op ieder moment stoppen. Alle data wordt anoniem verwerkt en opgeslagen, data wordt verwijdert na afronding van het gehele afstudeertraject.

*Vereist

1. *Markeer slechts één ovaal.*

   ◯ Optie 1

2. Gaat u akkoord met het bovenstaande? *

   Markeer slechts één ovaal.

   ◯ Ja *Ga naar sectie 2 (Modellen)*

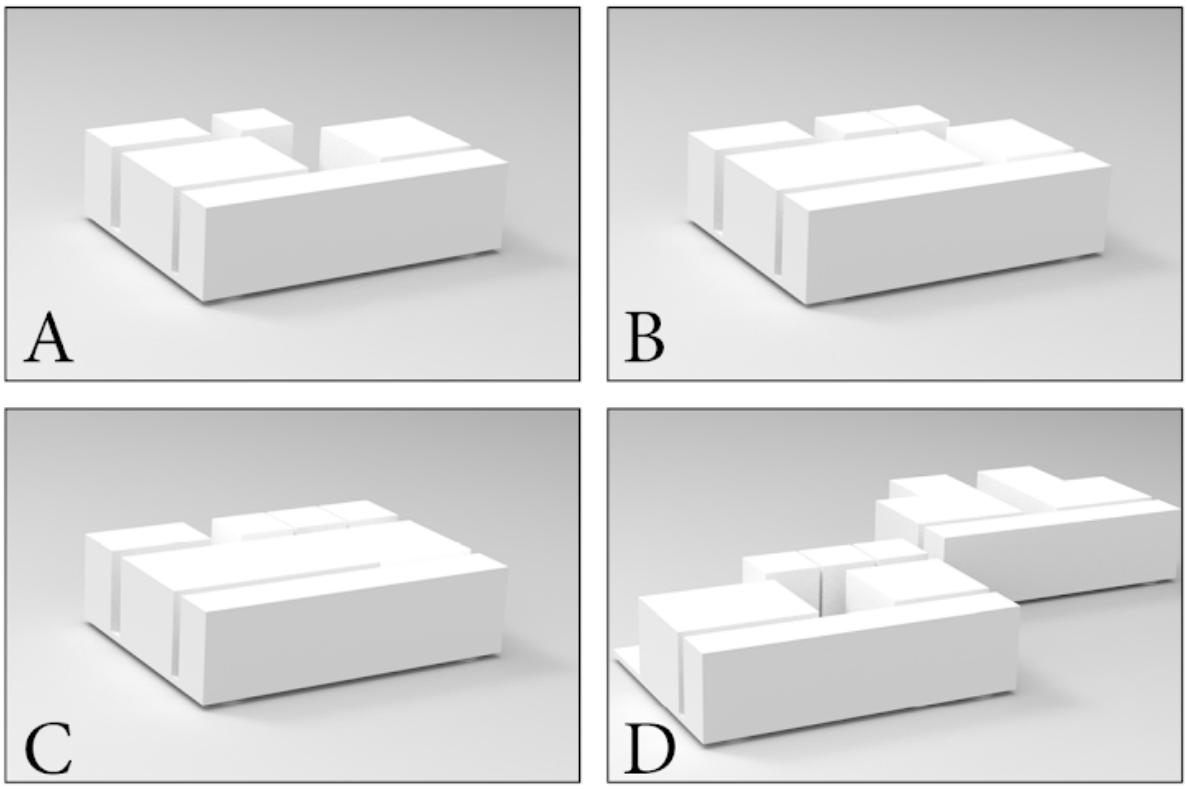
   ◯ Nee

Modellen

In deze eerste sectie krijgt u de vier verschillende modellen gepresenteerd. Elk model bestaat uit vier stages, Stage 1 (A), Stage 2(B), Stage 3(C) en Stage 4(D), waarbij Stage 1 het meest eenvoudig en betaalbaar is en Stage 4 het meest uitgebreid en geavanceerd.

Echter, voor nu gaat het om uw voorkeur met betrekking tot plaatsing en lay-out. De volgende vier vragen zullen hierover gaan. U wordt verzocht u antwoorden niet meer te veranderen, nadat u naar de volgende vraag bent geweest.

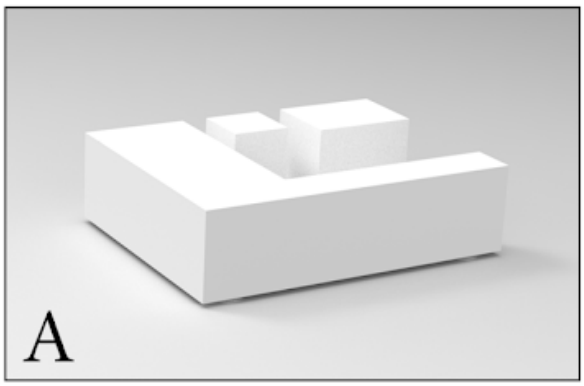
3. Rangschik figuren A tm D naar uw, esthetische, voorkeur. *

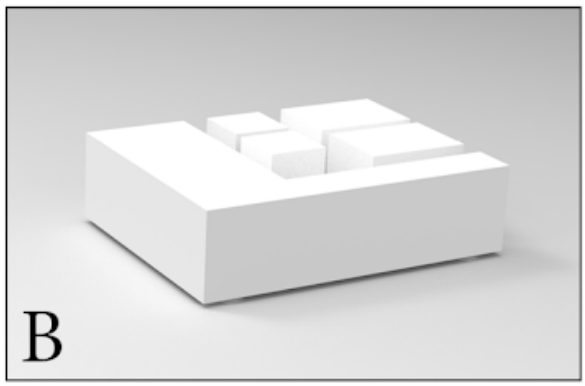


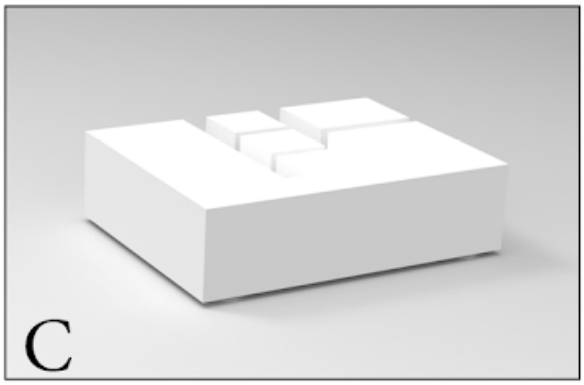
Markeer slechts één ovaal per rij.

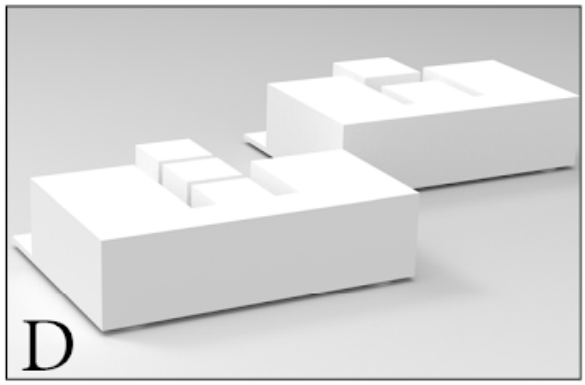
	A	B	C	D
1 (Most preferred)	◯	◯	◯	◯
2	◯	◯	◯	◯
3	◯	◯	◯	◯
4 (Least preferred)	◯	◯	◯	◯

4. Rangschik figuren A tm D naar uw, esthetische, voorkeur. *





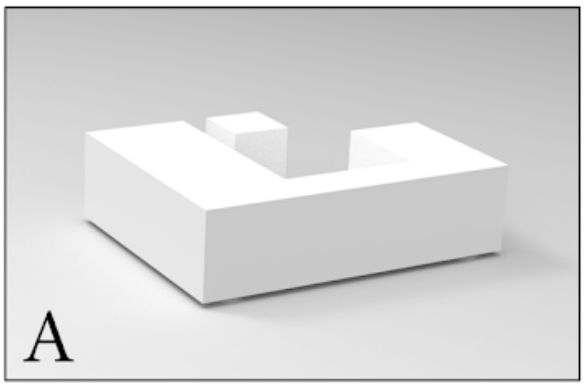


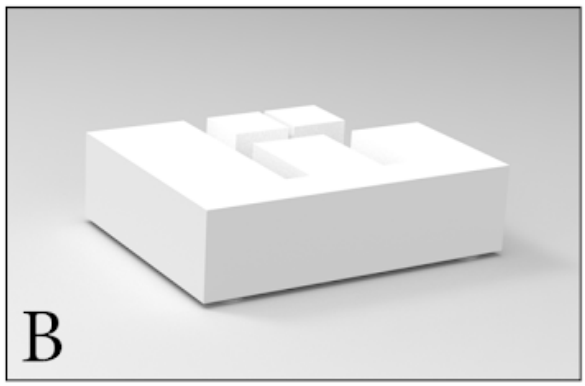


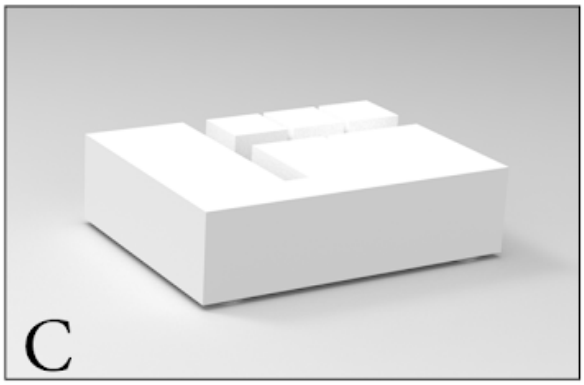
Markeer slechts één ovaal per rij.

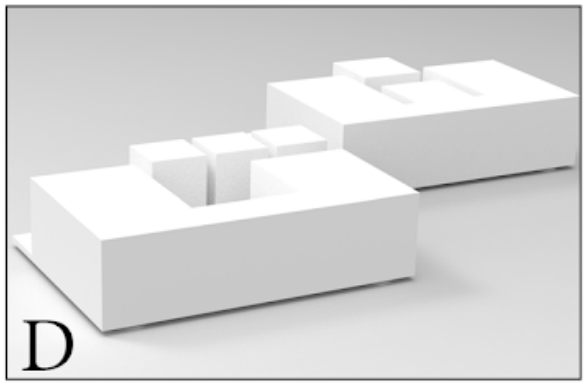
	A	B	C	D
1 (Most preferred)	◯	◯	◯	◯
2	◯	◯	◯	◯
3	◯	◯	◯	◯
4 (Least preferred)	◯	◯	◯	◯

5. Rangschik figuren A tm D naar uw, esthetische, voorkeur. *





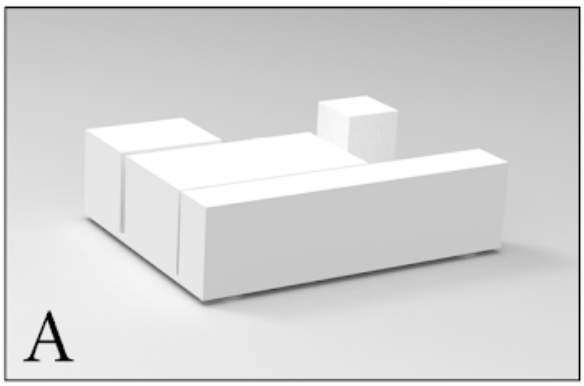


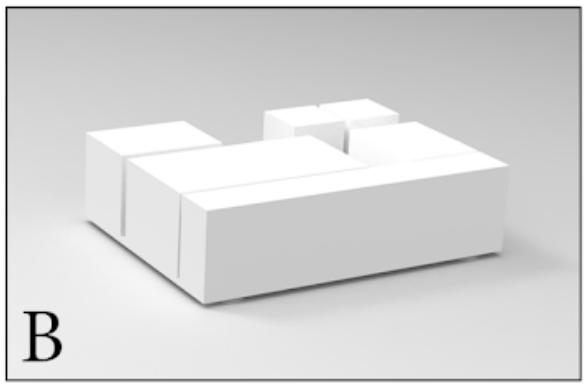


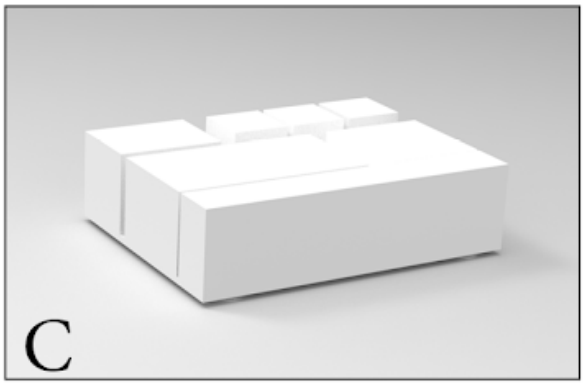
Markeer slechts één ovaal per rij.

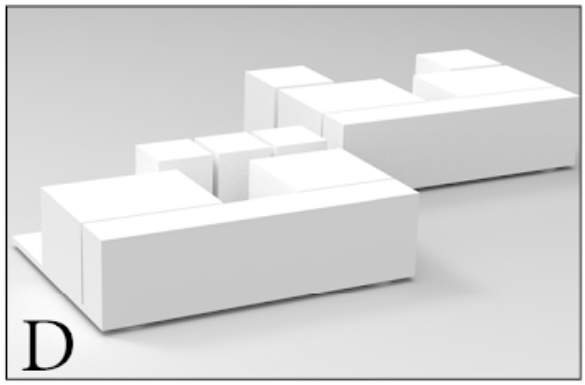
	A	B	C	D
1 (Most preferred)	◯	◯	◯	◯
2	◯	◯	◯	◯
3	◯	◯	◯	◯
4 (Least preferred)	◯	◯	◯	◯

6. Rangschik figuren A tm D naar uw, esthetische, voorkeur. *









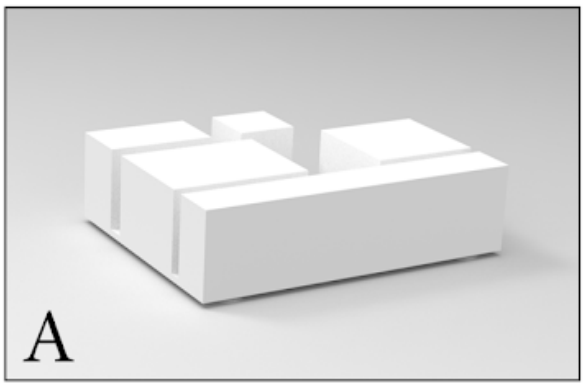
Markeer slechts één ovaal per rij.

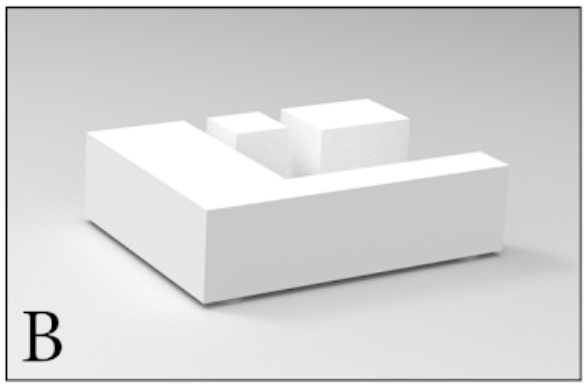
	A	B	C	D
1 (Most preferred)	◯	◯	◯	◯
2	◯	◯	◯	◯
3	◯	◯	◯	◯
4 (Least preferred)	◯	◯	◯	◯

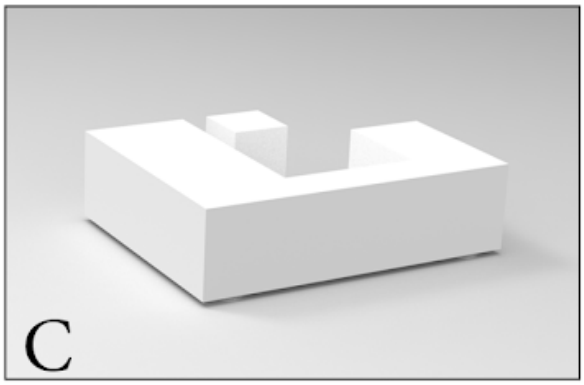
Stages

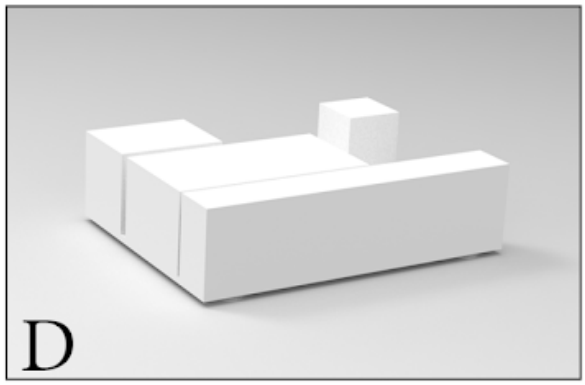
Welkom bij sectie twee. De afgelopen vier vragen bekeken elk model, met de vier bijbehorende stages, apart. In de komende vier vragen worden de stages onderling met elkaar vergeleken. Het gaat nog steeds om uw esthetische voorkeuren, dus goed en fout bestaat niet.

7. Rangschik figuren A tm D naar uw, esthetische, voorkeur. *





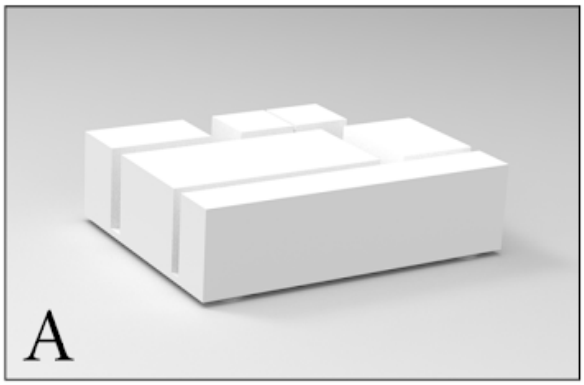


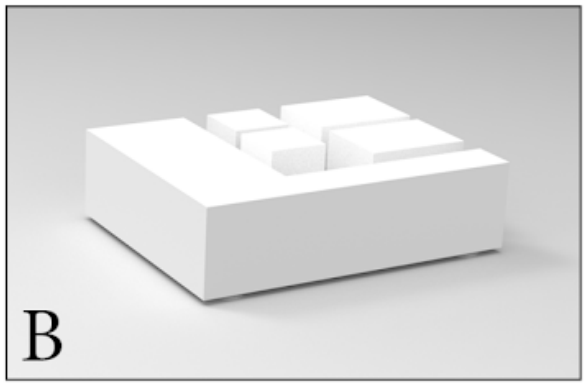


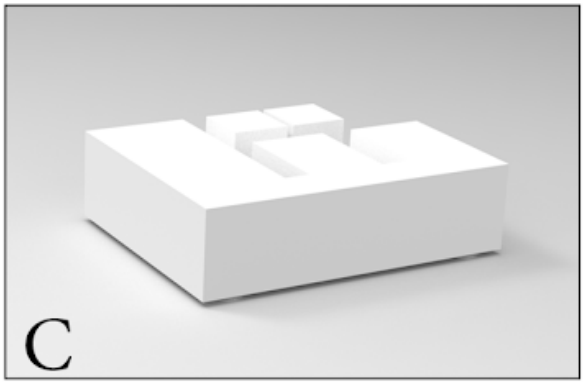
Markeer slechts één ovaal per rij.

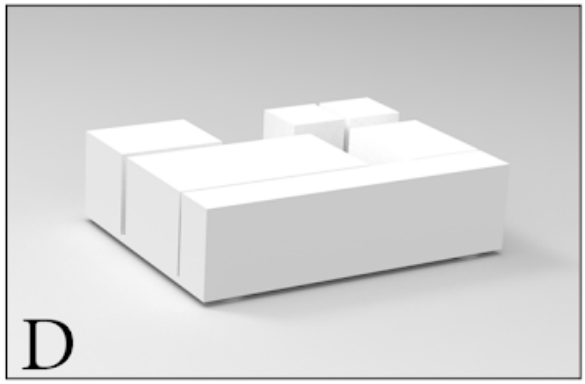
	A	B	C	D
1 (Most preferred)	◯	◯	◯	◯
2	◯	◯	◯	◯
3	◯	◯	◯	◯
4 (Least preferred)	◯	◯	◯	◯

8. Rangschik figuren A tm D naar uw, esthetische, voorkeur. *





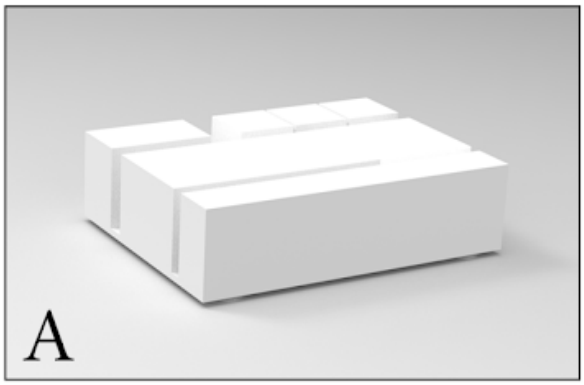


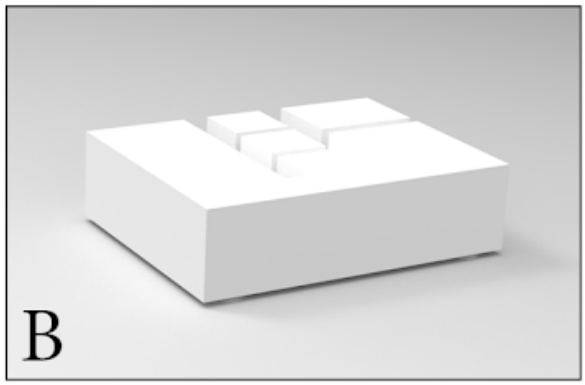


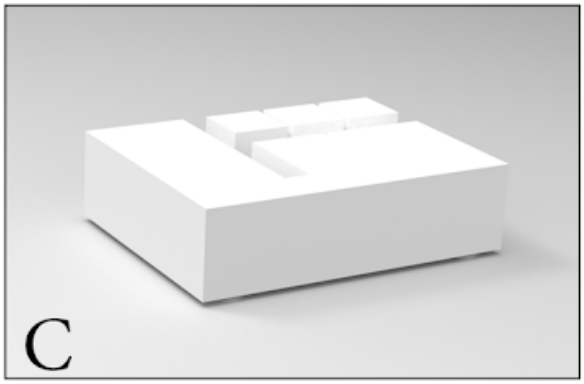
Markeer slechts één ovaal per rij.

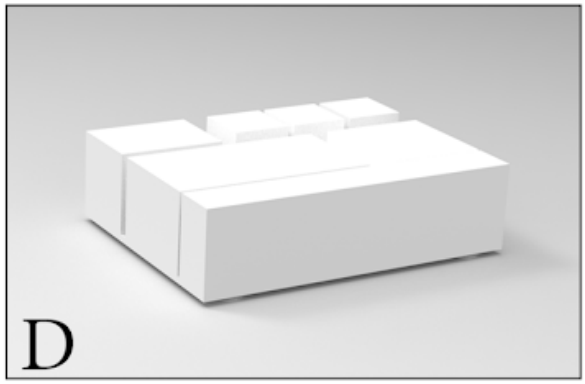
	A	B	C	D
1 (Most preferred)	◯	◯	◯	◯
2	◯	◯	◯	◯
3	◯	◯	◯	◯
4 (Least preferred)	◯	◯	◯	◯

9. Rangschik figuren A tm D naar uw, esthetische, voorkeur. *





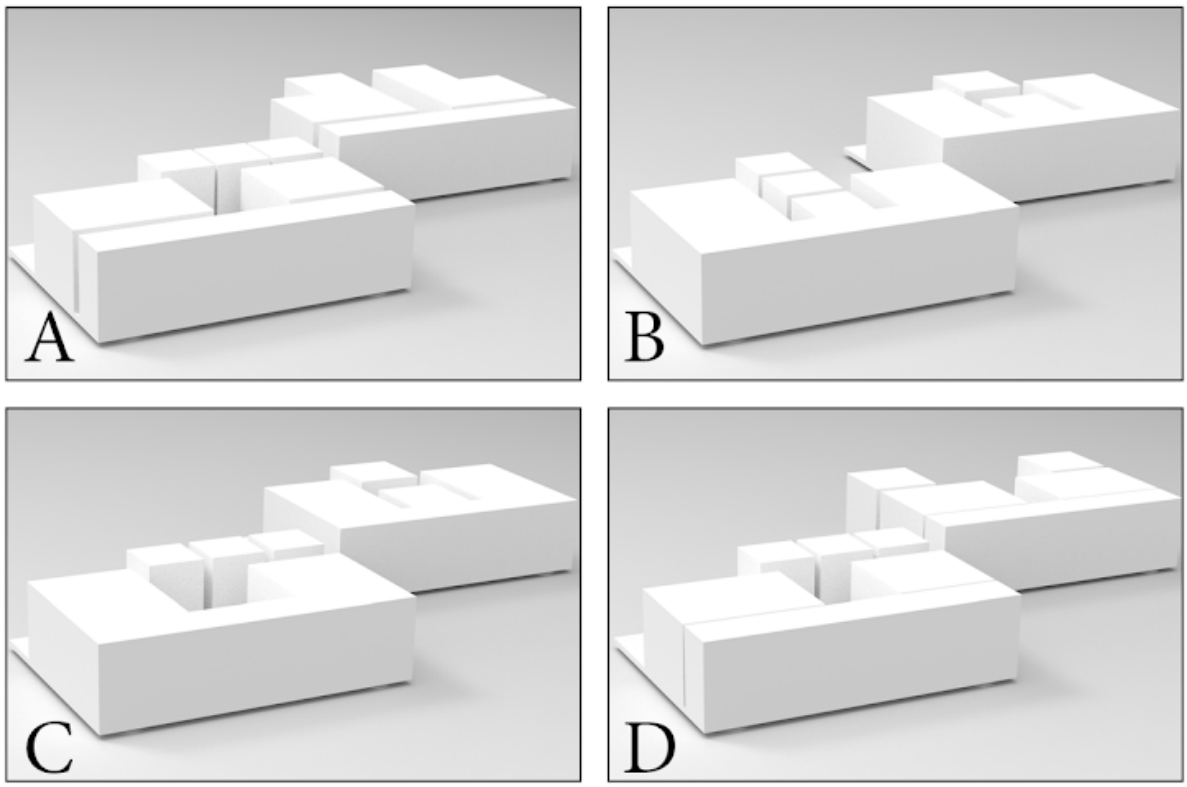




Markeer slechts één ovaal per rij.

	A	B	C	D
1 (Most preferred)	◯	◯	◯	◯
2	◯	◯	◯	◯
3	◯	◯	◯	◯
4 (Least preferred)	◯	◯	◯	◯

10. Rangschik figuren A tm D naar uw, esthetische, voorkeur. *



Markeer slechts één ovaal per rij.

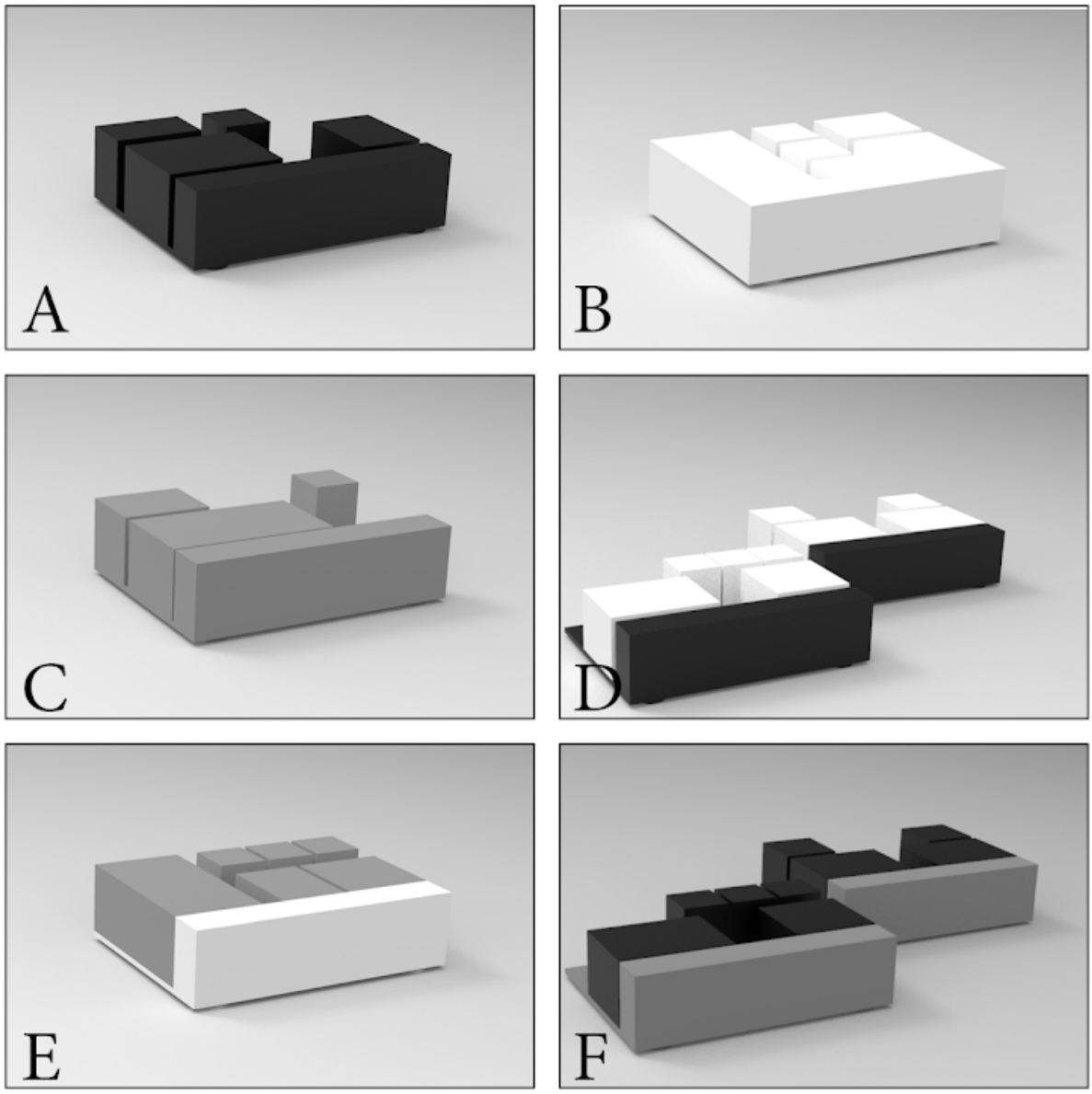
	A	B	C	D
1 (Most preferred)	◯	◯	◯	◯
2	◯	◯	◯	◯
3	◯	◯	◯	◯
4 (Least preferred)	◯	◯	◯	◯

Kleuren

De verschillende modellen en stages zijn nu een aantal keer gepasseerd, tijd om kleur toe te voegen. In de komende zes vragen mag u de zes gepresenteerde figuren wederom rangschikken naar esthetische voorkeur, welke trekt u het meest en welke het minst.

Kleuren

11. Rangschik figuren A tm F naar uw, esthetische, voorkeur. *

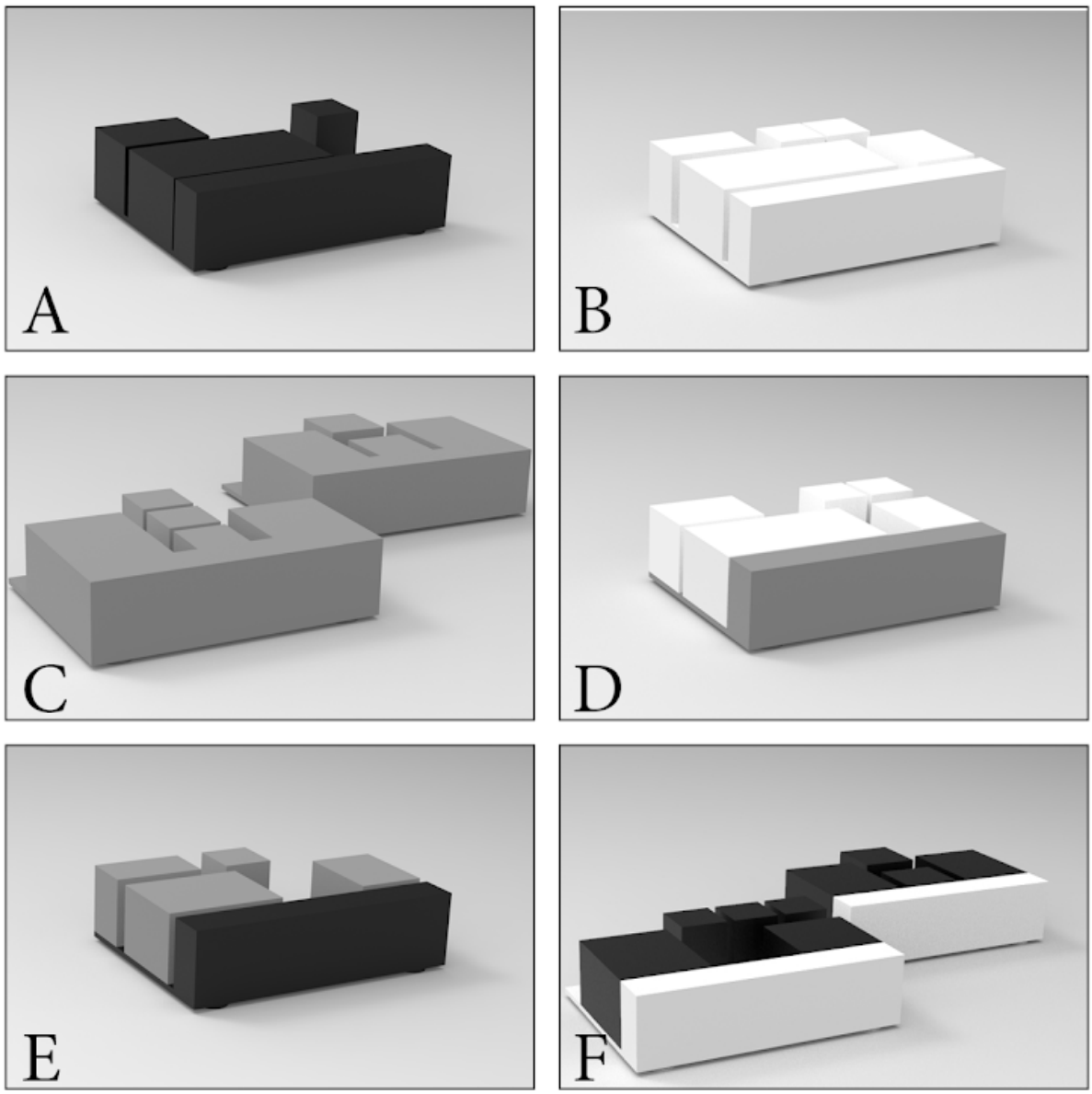


Markeer slechts één ovaal per rij.

	A	B	C	D	E	F
1 (Most preferred)	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯
6 (Least preferred)	◯	◯	◯	◯	◯	◯

Naamloze sectie

12. Rangschik figuren A tm F naar uw, esthetische, voorkeur. *

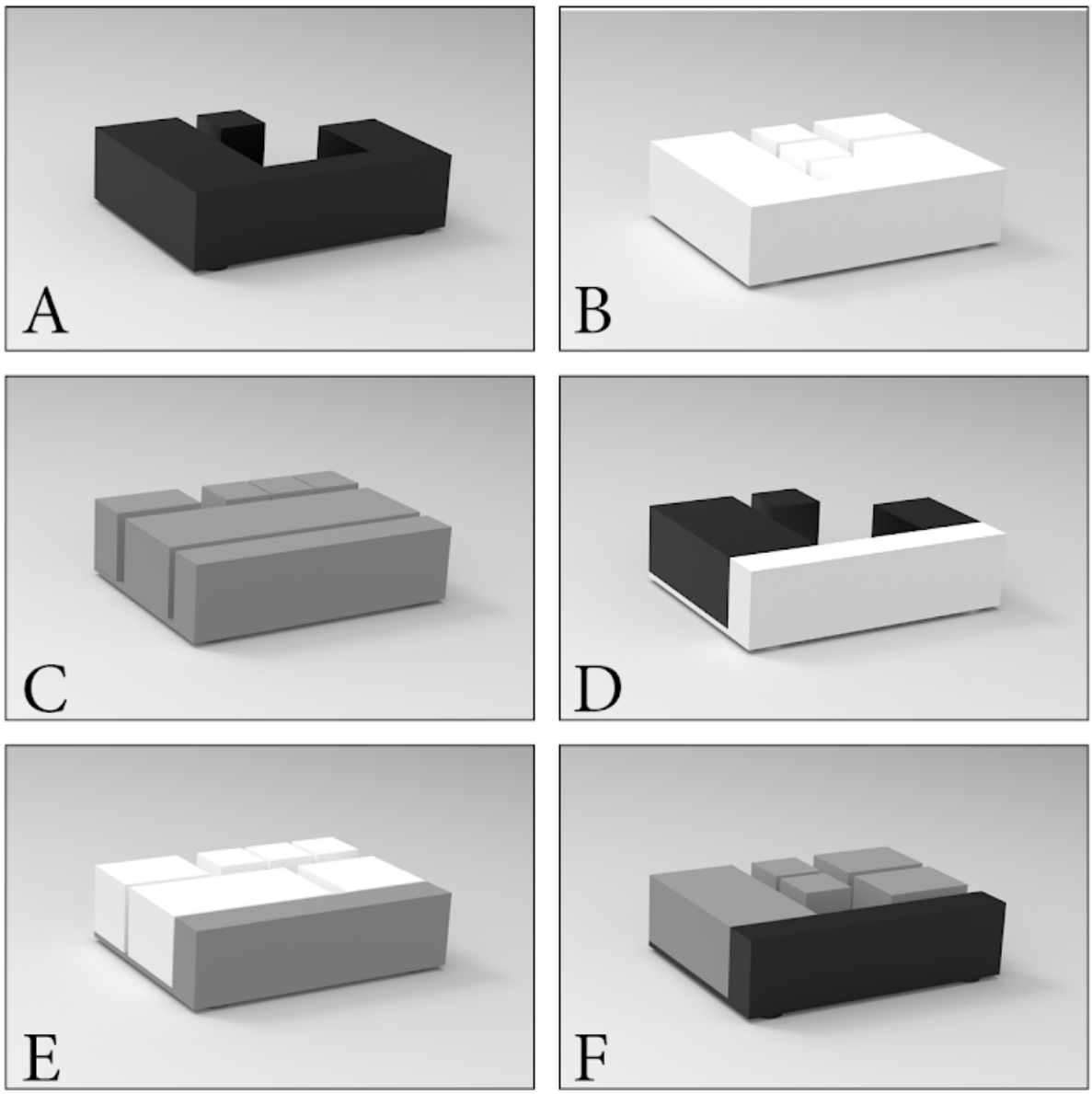


Markeer slechts één ovaal per rij.

	A	B	C	D	E	F
1 (Most preferred)	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯
6 (Least preferred)	◯	◯	◯	◯	◯	◯

Naamloze sectie

13. Rangschik figuren A tm F naar uw, esthetische, voorkeur. *

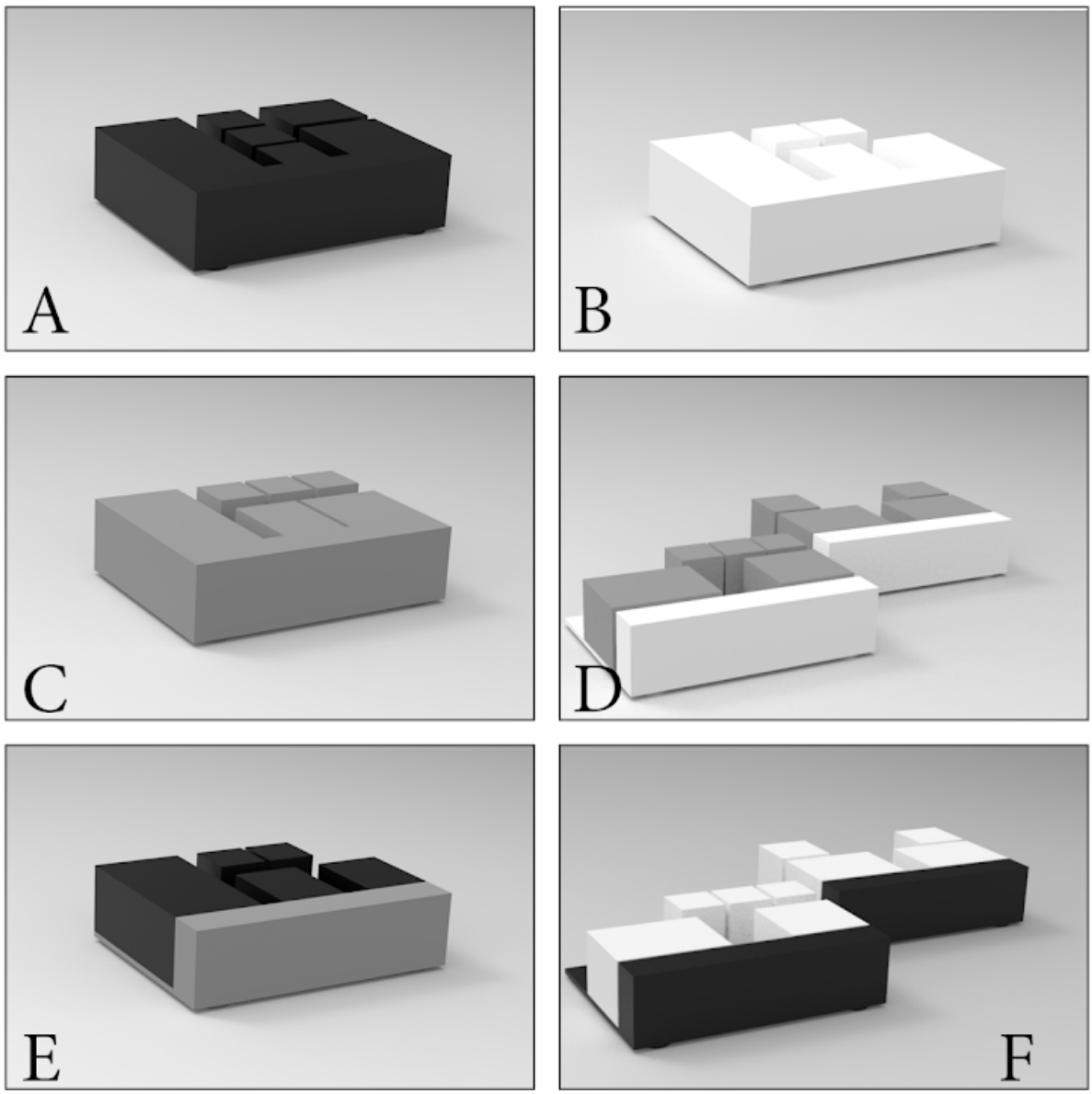


Markeer slechts één ovaal per rij.

	A	B	C	D	E	F
1 (Most preferred)	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯
6 (Least preferred)	◯	◯	◯	◯	◯	◯

Naamloze sectie

14. Rangschik figuren A tm F naar uw, esthetische, voorkeur. *

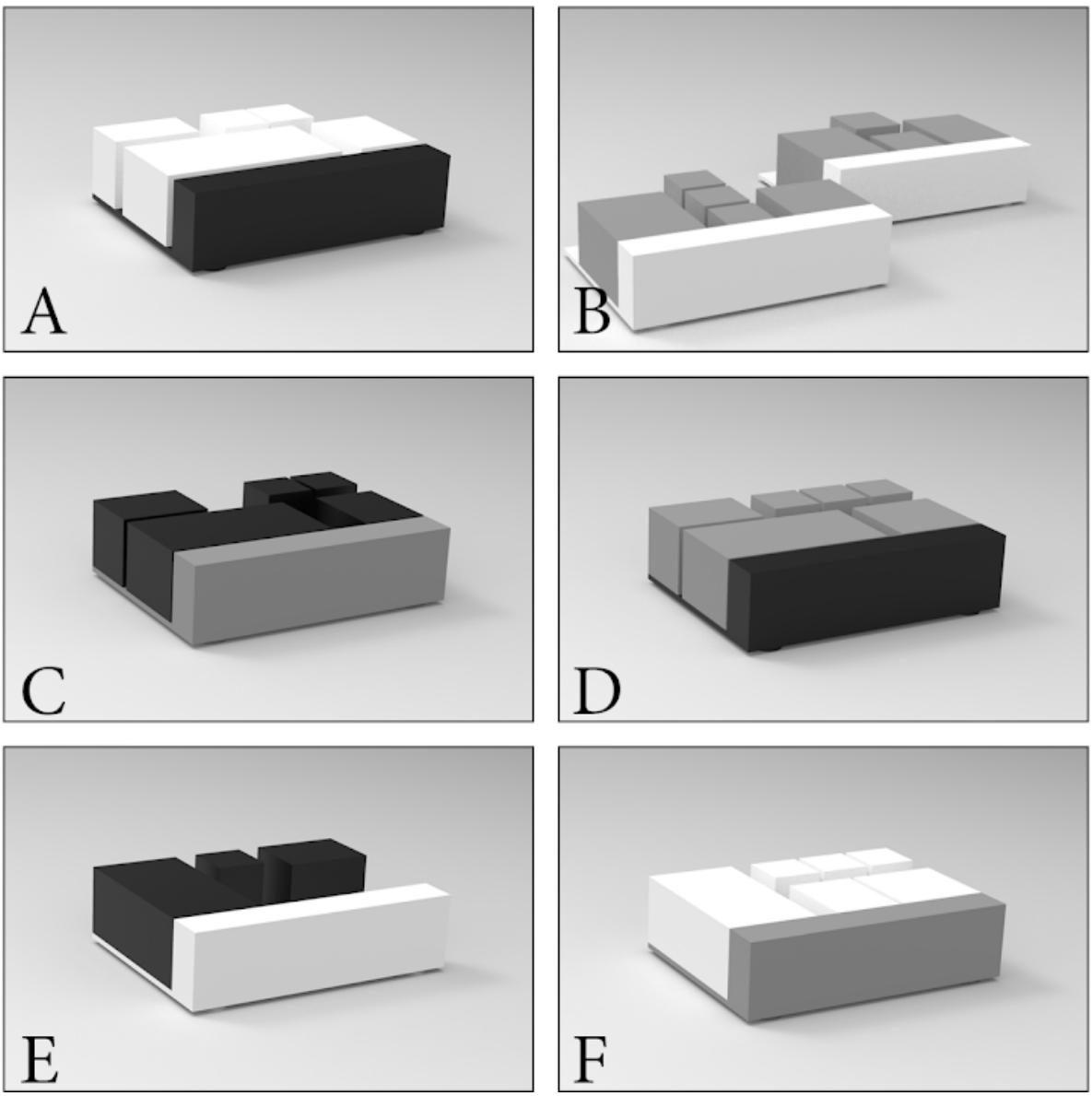


Markeer slechts één ovaal per rij.

	A	B	C	D	E	F
1 (Most preferred)	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯
6 (Least preferred)	◯	◯	◯	◯	◯	◯

Naamloze sectie

15. Rangschik figuren A tm F naar uw, esthetische, voorkeur. *

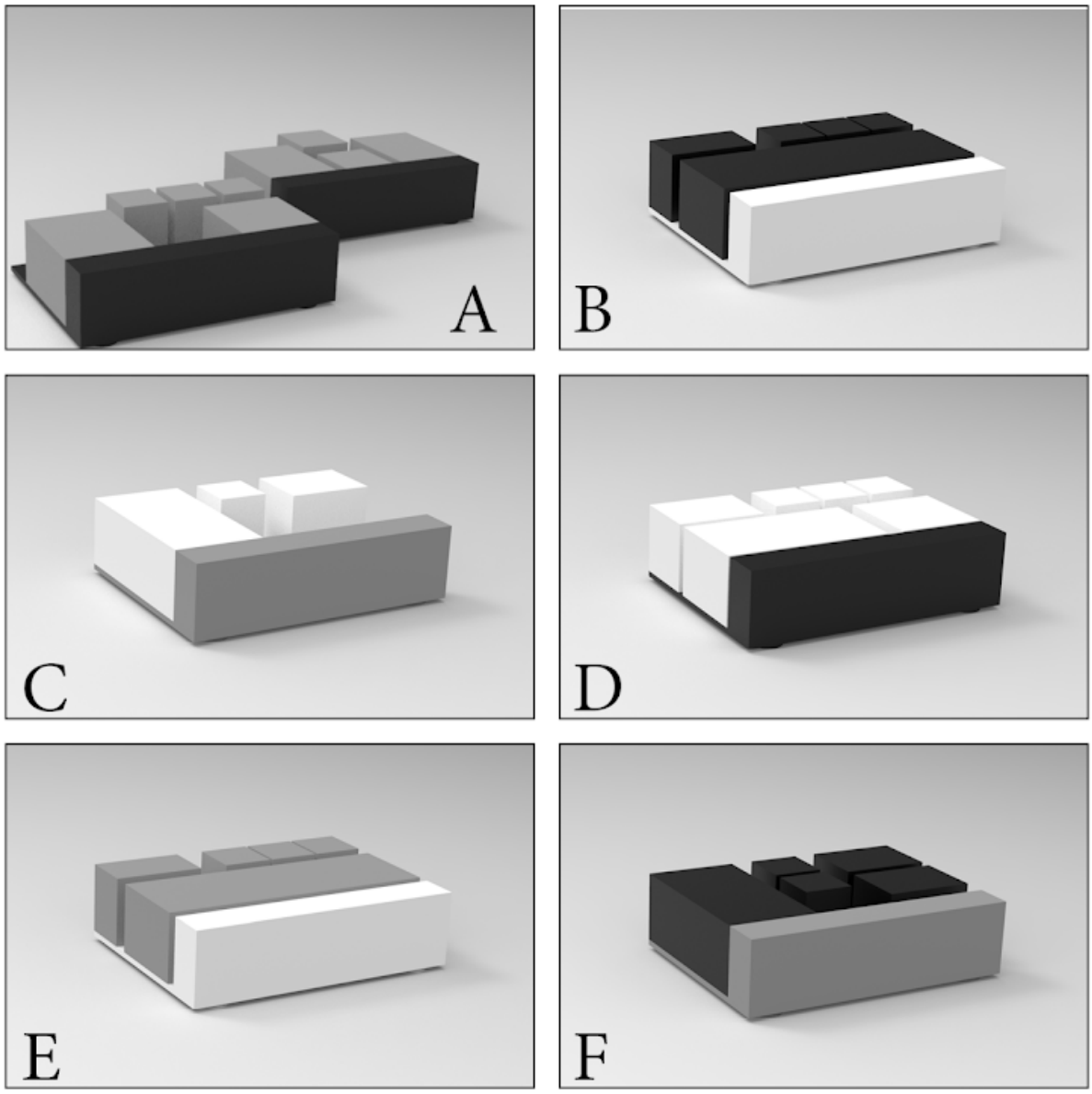


Markeer slechts één ovaal per rij.

	A	B	C	D	E	F
1 (Most preferred)	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯
6 (Least preferred)	◯	◯	◯	◯	◯	◯

Naamloze sectie

16. Rangschik figuren A tm F naar uw, esthetische, voorkeur. *



Markeer slechts één ovaal per rij.

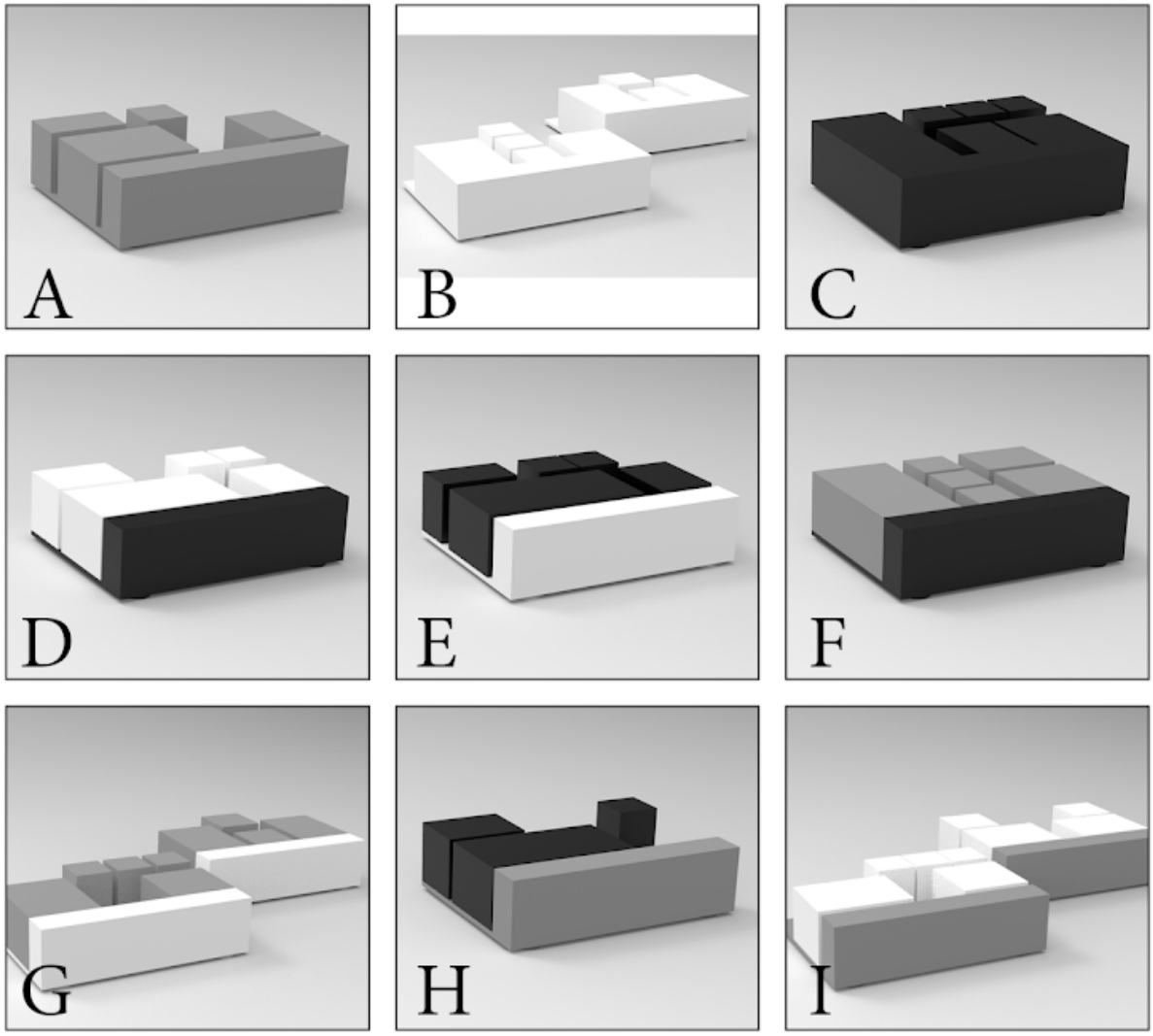
	A	B	C	D	E	F
1 (Most preferred)	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯
6 (Least preferred)	◯	◯	◯	◯	◯	◯

Kleur & Lay-out

U bent aangekomen bij de laatste vier vragen met betrekking tot uw esthetische voorkeur. Dit keer krijgt u negen afbeeldingen in een keer te zien, maar de opdracht blijft hetzelfde, rangschik ze naar uw voorkeur.

Naamloze sectie

17. Rangschik figuren A tm I naar uw, esthetische, voorkeur. *

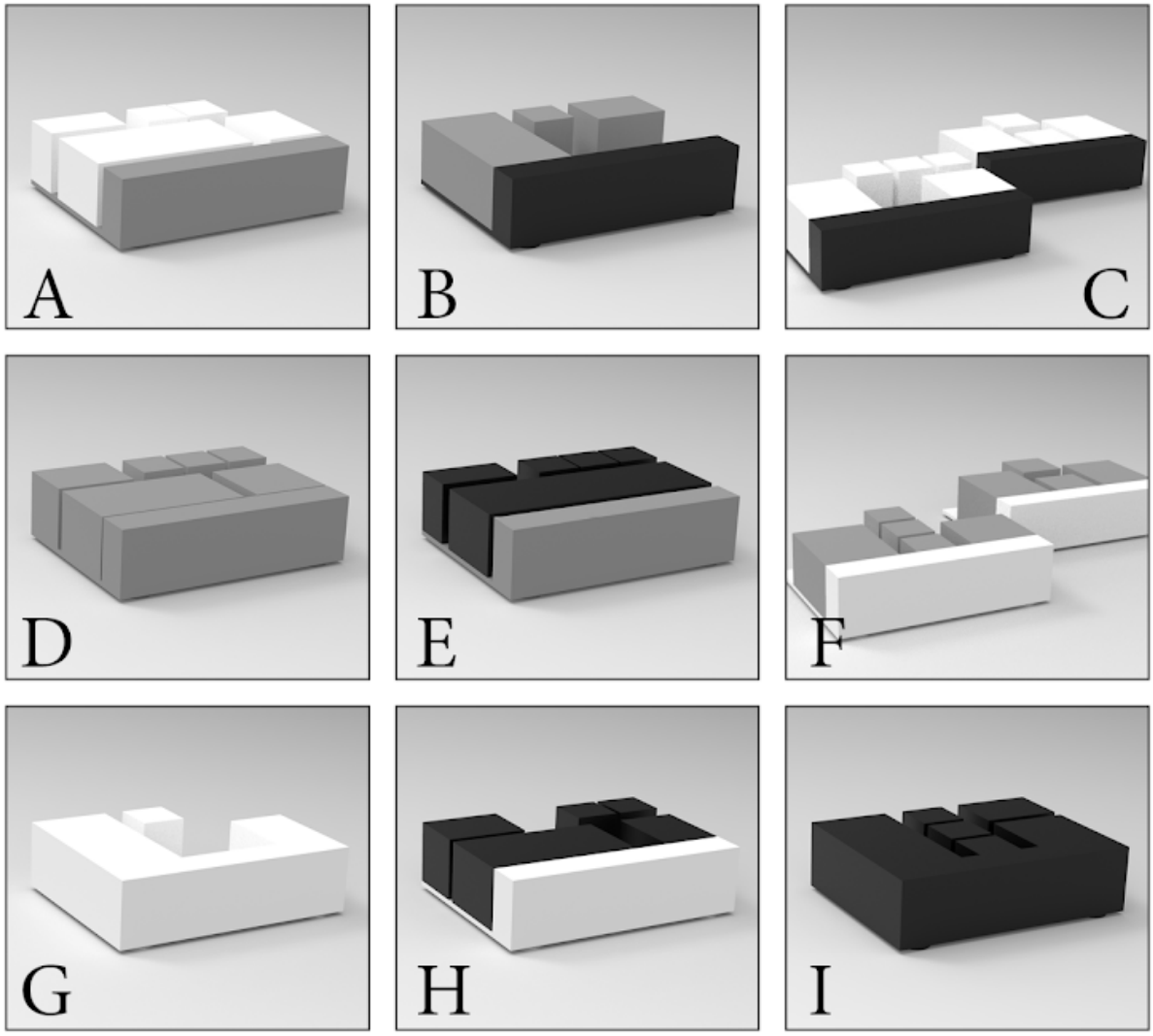


Markeer slechts één ovaal per rij.

	A	B	C	D	E	F	G	H	I
1 (Most preferred)	◯	◯	◯	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯	◯	◯	◯
6	◯	◯	◯	◯	◯	◯	◯	◯	◯
7	◯	◯	◯	◯	◯	◯	◯	◯	◯
8	◯	◯	◯	◯	◯	◯	◯	◯	◯
9 (Least	◯	◯	◯	◯	◯	◯	◯	◯	◯

preferred)

18. Rangschik figuren A tm I naar uw, esthetische, voorkeur. *

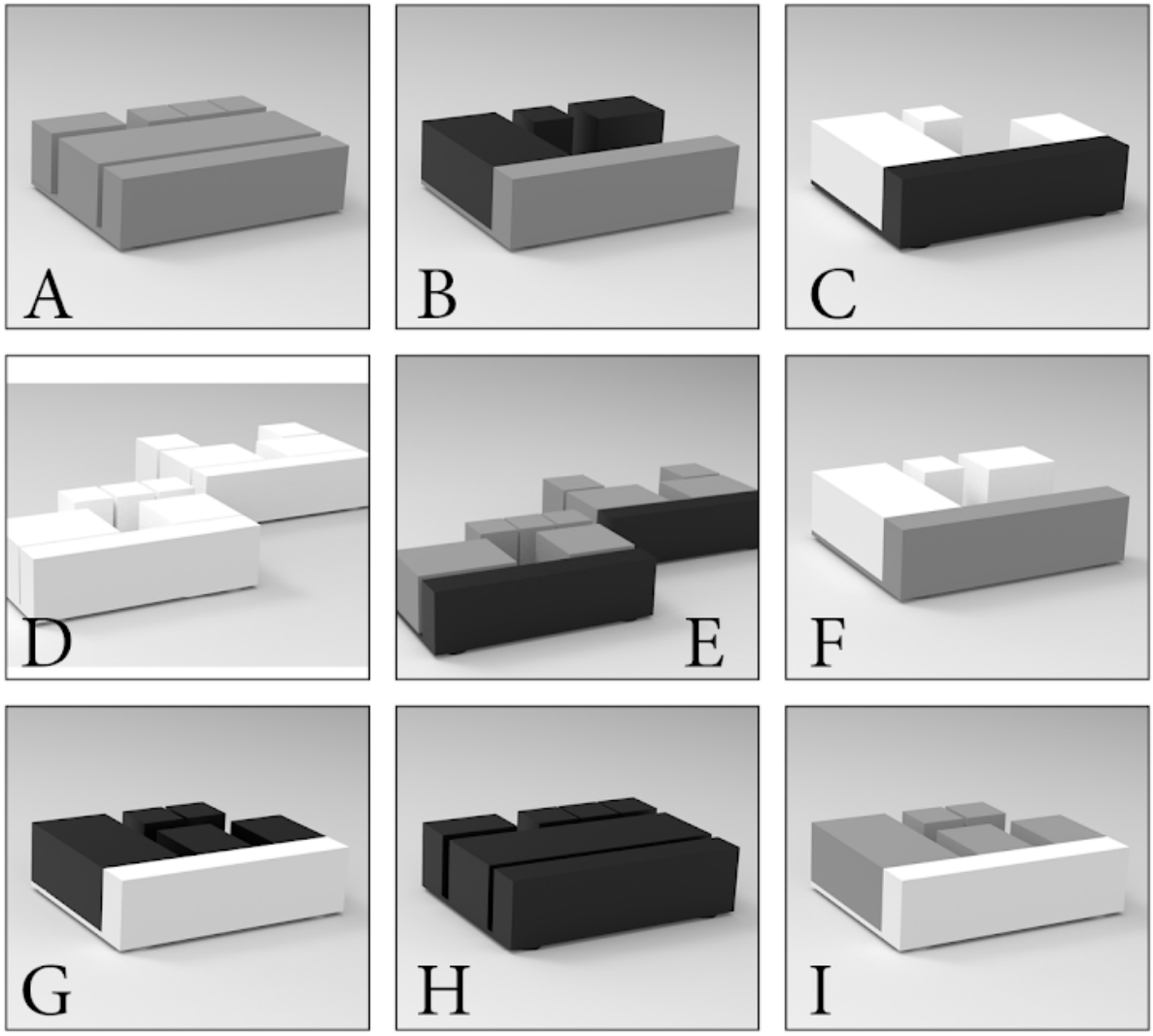


Markeer slechts één ovaal per rij.

	A	B	C	D	E	F	G	H	I
1 (Most preferred)	◯	◯	◯	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯	◯	◯	◯
6	◯	◯	◯	◯	◯	◯	◯	◯	◯
7	◯	◯	◯	◯	◯	◯	◯	◯	◯
8	◯	◯	◯	◯	◯	◯	◯	◯	◯
9 (Least	◯	◯	◯	◯	◯	◯	◯	◯	◯

preferred)

19. Rangschik figuren A tm I naar uw, esthetische, voorkeur. *

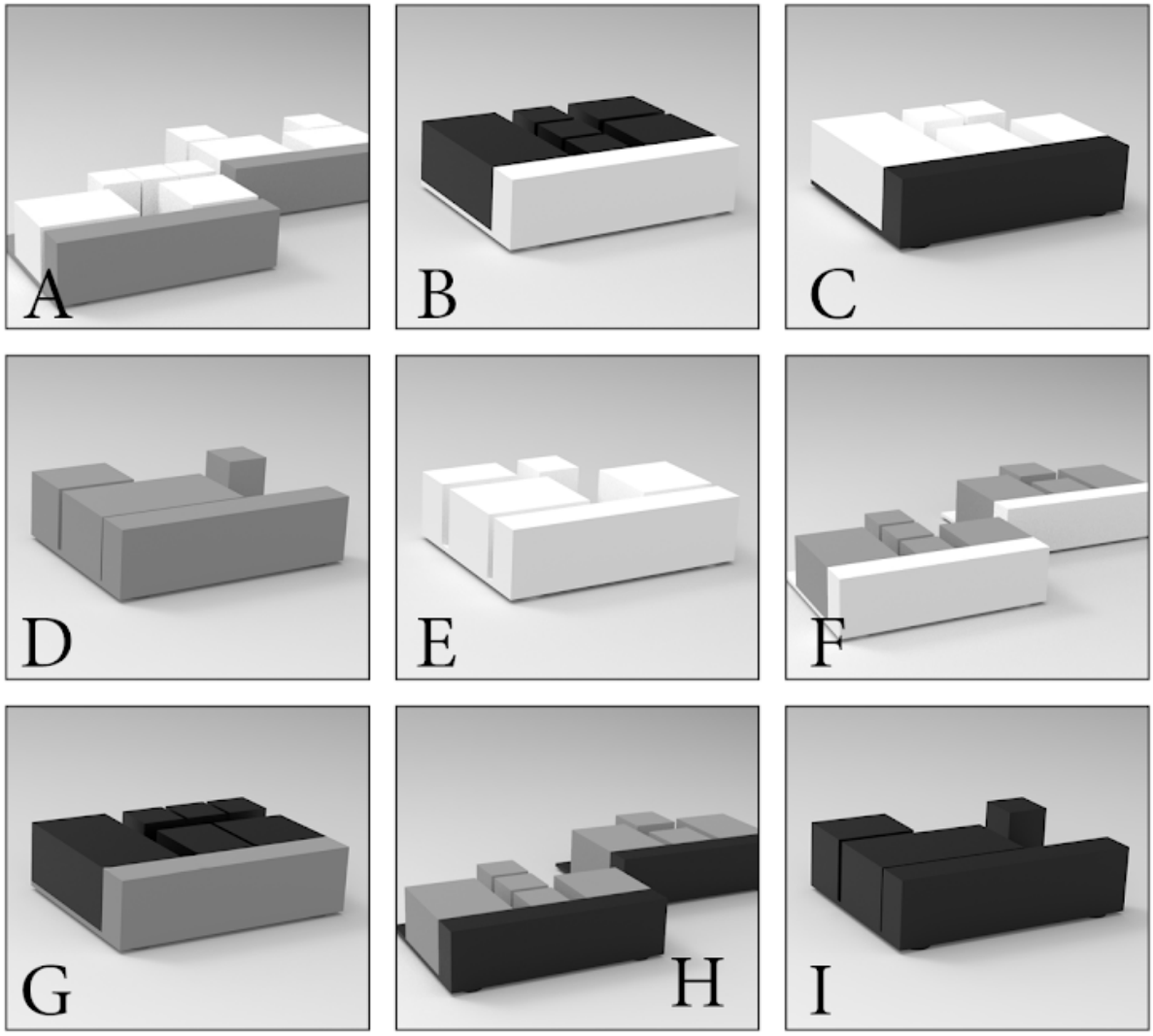


Markeer slechts één ovaal per rij.

	A	B	C	D	E	F	G	H	I
1 (Most preferred)	◯	◯	◯	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯	◯	◯	◯
6	◯	◯	◯	◯	◯	◯	◯	◯	◯
7	◯	◯	◯	◯	◯	◯	◯	◯	◯
8	◯	◯	◯	◯	◯	◯	◯	◯	◯
9 (Least	◯	◯	◯	◯	◯	◯	◯	◯	◯

preferred)

20. Rangschik figuren A tm I naar uw, esthetische, voorkeur. *



Markeer slechts één ovaal per rij.

	A	B	C	D	E	F	G	H	I
1 (Most preferred)	◯	◯	◯	◯	◯	◯	◯	◯	◯
2	◯	◯	◯	◯	◯	◯	◯	◯	◯
3	◯	◯	◯	◯	◯	◯	◯	◯	◯
4	◯	◯	◯	◯	◯	◯	◯	◯	◯
5	◯	◯	◯	◯	◯	◯	◯	◯	◯
6	◯	◯	◯	◯	◯	◯	◯	◯	◯
7	◯	◯	◯	◯	◯	◯	◯	◯	◯
8	◯	◯	◯	◯	◯	◯	◯	◯	◯
9 (Least	◯	◯	◯	◯	◯	◯	◯	◯	◯

preferred)

General information

21. Wat is uw (biologisch) geslacht

Markeer slechts één ovaal.

- Man
- Vrouw
- Zeg ik liever niet

22. Wat is uw leeftijd

Markeer slechts één ovaal.

- <20
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70-79
- 80-89
- 90-99
- 99+

23. Indien u nog vragen of opmerkingen heeft, kunt u deze hieronder kwijt. Ik lees ze graag.

Ga naar sectie 25 (Hartelijk dank voor uw medewerking)

Hartelijk dank voor uw medewerking

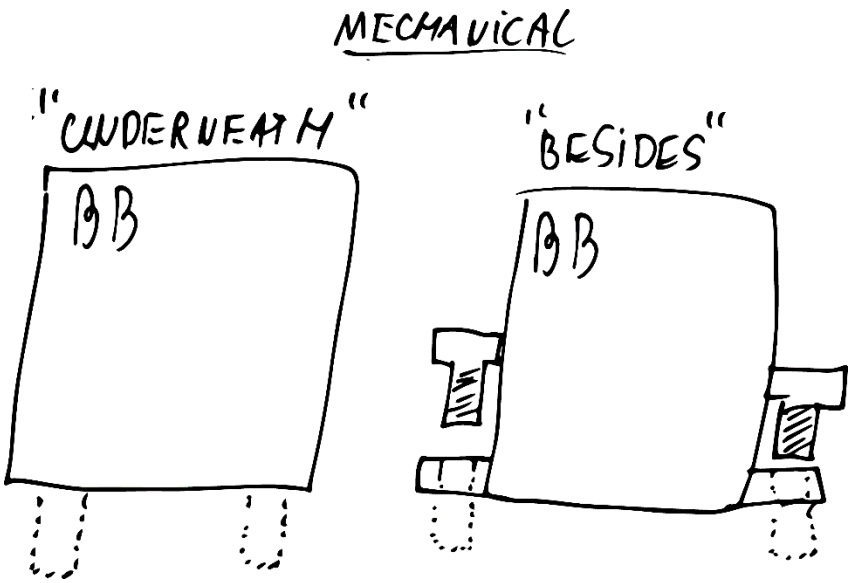
Hiermee zijn we aan het eind gekomen van dit onderzoek. Ik wil u, wederom, hartelijk danken voor uw deelname en zal spoedig weer contact opnemen voor nog twee onderzoeken. Deze gaan beide over het plaatsen en aansluiten van de verschillende modules, zodat u er veilig en zelf mee kunt werken.

Voor nu een prettige dag verder en tot de volgende.

Appendix O – Attachment Options & Concepts

Attachment Options

Mechanical Connection



Mechanical connections rely on mechanical principles to hold the building blocks in place.

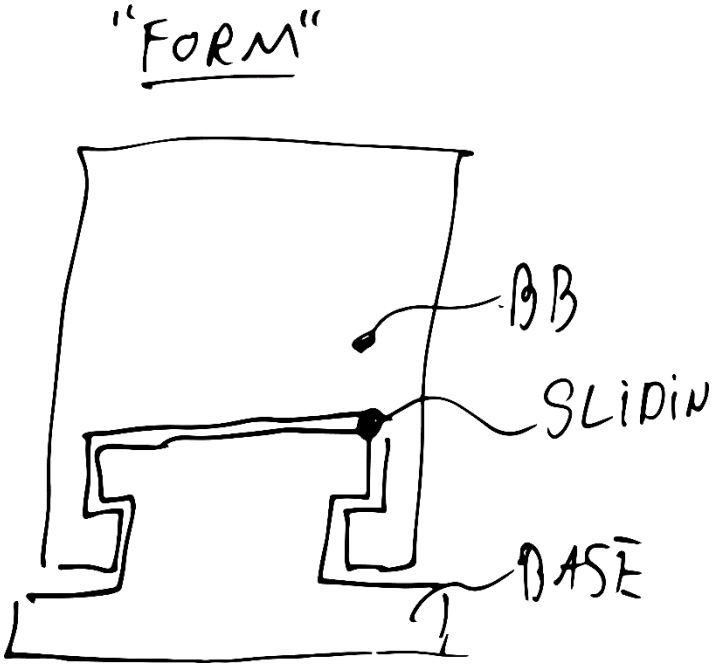
Benefits

Mechanical connections are, in most cases, reusable.

Drawbacks

Mechanical principles often have (semi) moving parts, that can wear down and need to be replaced.

Form Connection



Form connections rely on physical properties of materials to keep them in place. Form connections can be, amongst others, a snap connections, a dovetail joint or the way a picture frame is hung.

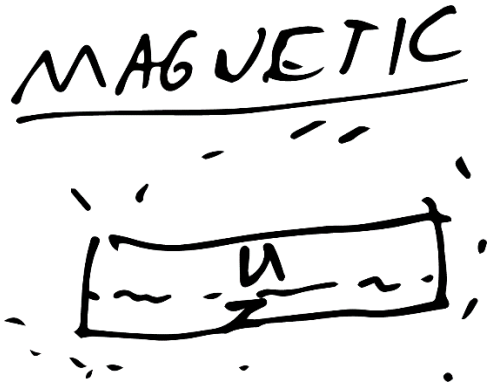
Benefits

Form connections do not rely on moving parts and can therefore be used “indefinitely”.

Drawbacks

Form connections need room to move to make the connection.

Magnetic Connection



Magnetic connections rely on the magnetic properties of magnets and steel materials. The steel is held in place by the magnetic field exerted by the magnet, which pulls or pushes on other ferromagnetic materials.

Benefits

Magnets can be integrated in objects, there is no physical contact needed between the two surfaces.

Drawbacks

Magnets can lose their magnetic field over time. Magnet production is not always sustainable.

Adhesives

Adhesives rely on material specific properties, glue and resins are two familiar types of adhesives.

Benefits

There is an adhesive to hold almost every type of material together (there are some plastics which are hard/impossible to glue, PP for instance).

Drawbacks

A strong connection by adhesives can not be reused if loosened. It has to be reapplied.

Building Block – Base connection options

Slider connection

Connection type: Form Connection

Description: Two variants of a ‘slider’ connection are tested. The First is based on blind hanging mechanism, often used for picture frames. In figure X a rough sketch can be seen, and in Figure X the printed prototype. The prototype revealed a weakness in this application. The fact that there is room to move sideways made it difficult to undo the connection, because the holes need to align exact.

Sketch

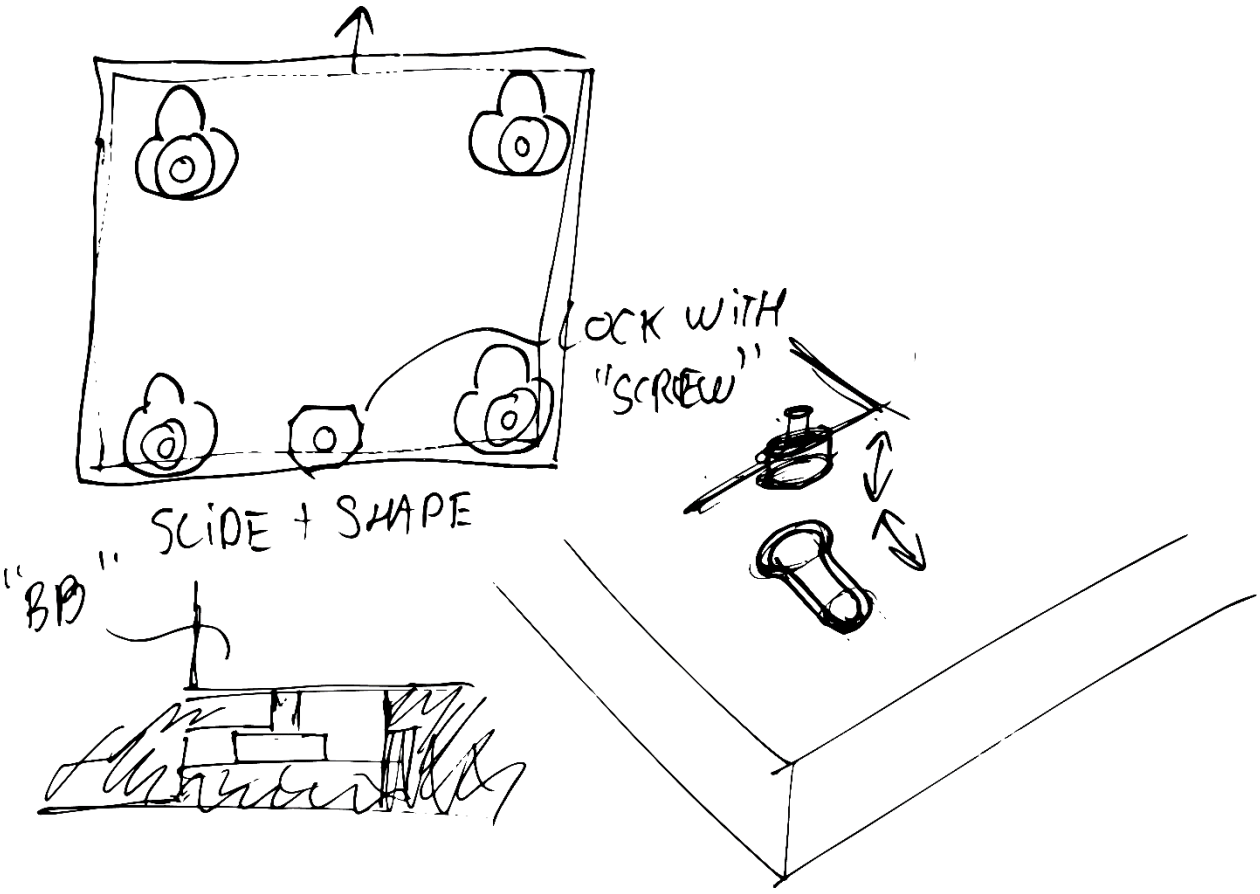


Figure X: Picture frame Prototype of slider connection.

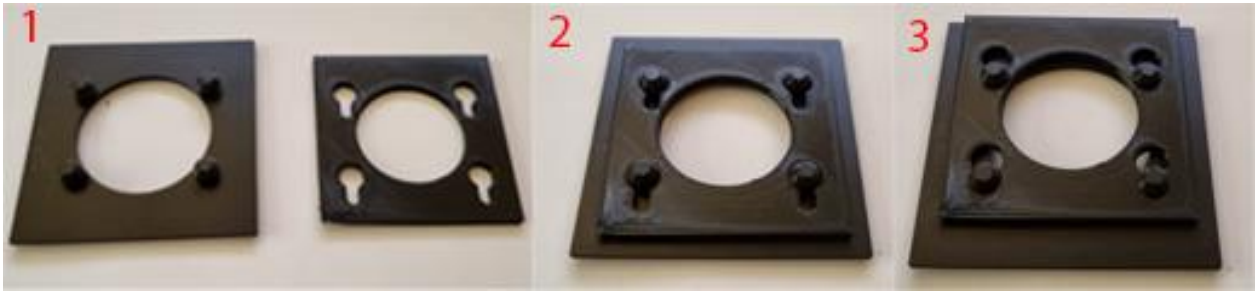


Figure X: 3D printed prototype of working principle Round.

To counter this difficulty a new design was made and tested which should solve this issue. A “finger” falls into the Base and is pushed sideways, locking the finger underneath. In figure X a sideview of the new design can be seen. Thereafter the finger is blocked, secured in place, by a plug, which is pushed into the base, behind the finger. In figure X the printed prototype and working can be seen.

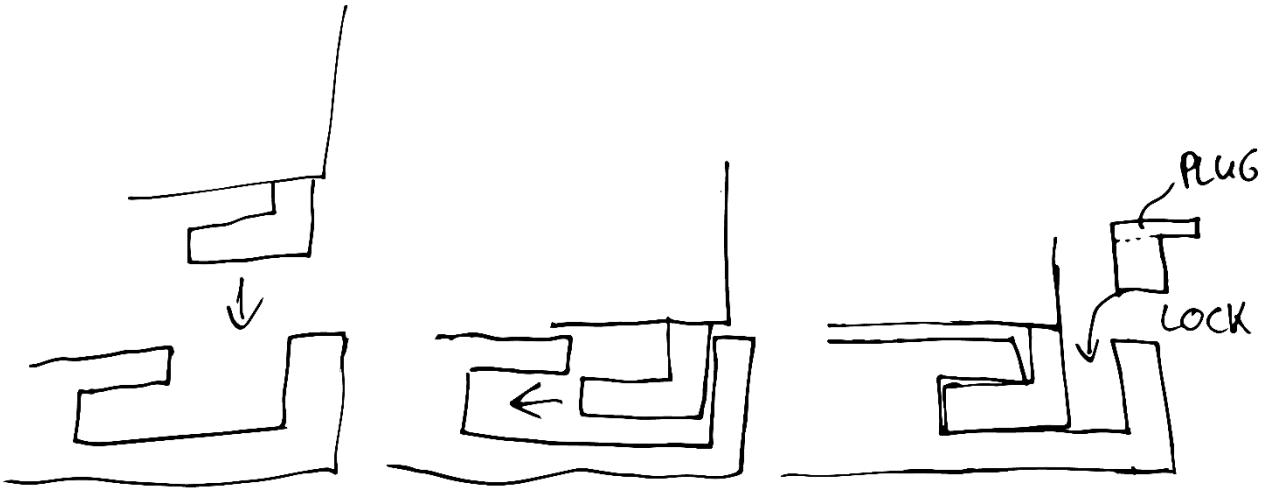


Figure X: Hook type slider connection

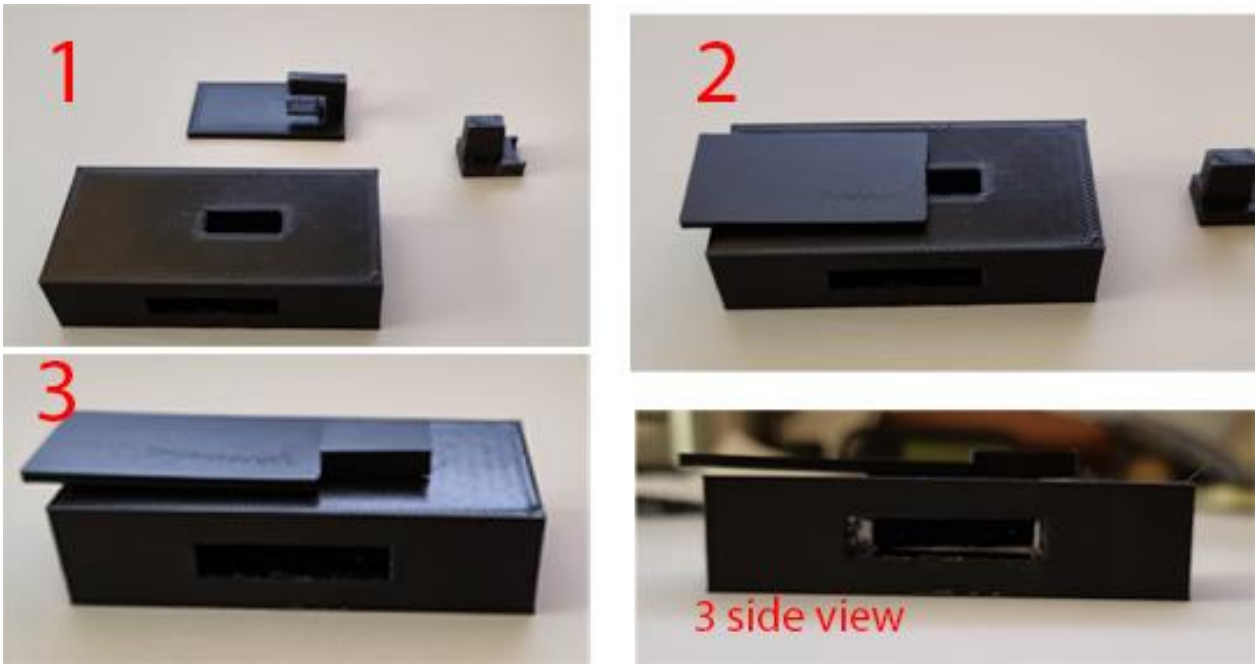


Figure X: 3d printed prototype of working principle

Do’s

- No moving parts
- Installation from one side

Don’ts

- Building blocks need room to move
- Might be a certain order in which blocks are placed.

“Ball” Spring

Connection type: Mechanical connection

The Ball Spring connection concept locks the building blocks in place using a mechanical connection. To the bottom of the building block four pins are connected. The pins fall into holes in the Base, under which the locking mechanism is placed. The locking mechanism is made up of two balls, or four flat parts, which are pushed inwards by springs. The Pin, attached to the Building Block, pushes the balls sideways, after which they lock the pin in place by the force exerted by the springs. The two variants can be seen in figure X and X.

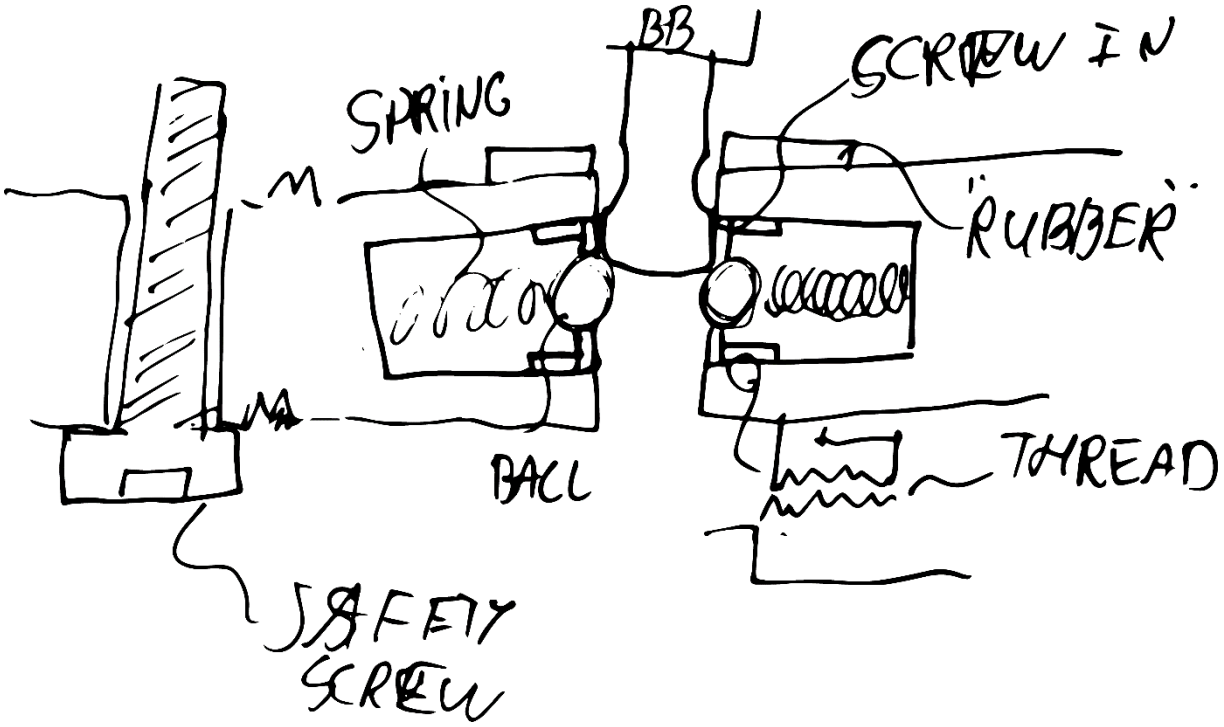


Figure X: Pin pushed between two Balls(left, right) locks the pin in place.

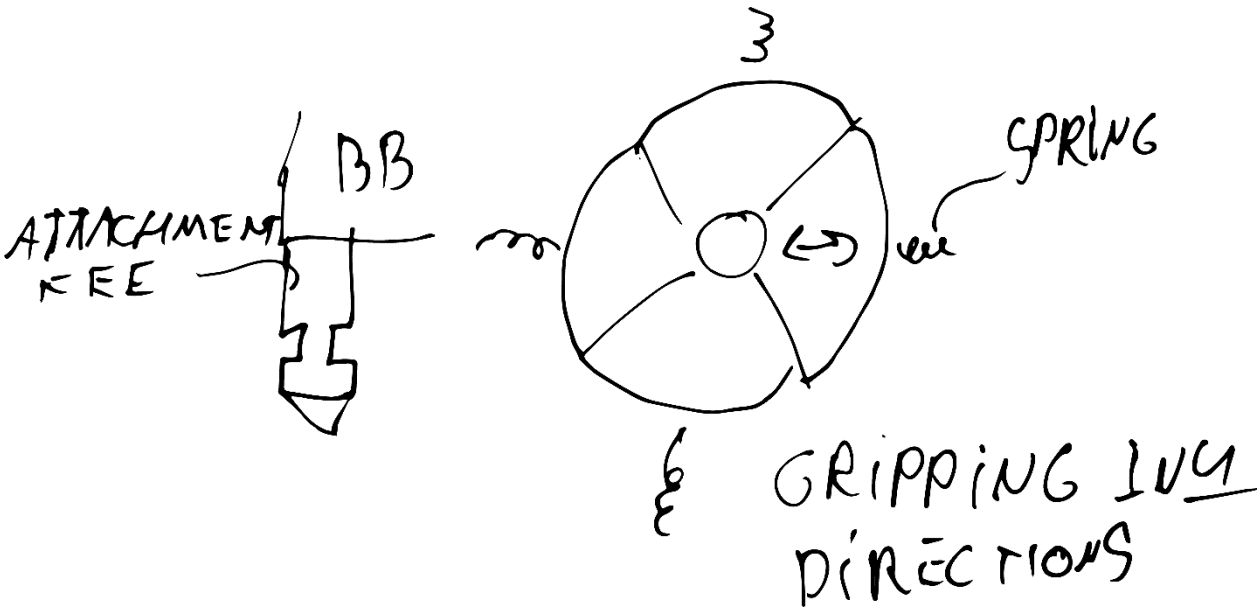


Figure X: The balls can be replaced by flat parts, which grip the feet in four directions.

A simplified version is tested, see figure X, where the complexity of the mechanism immediately became clear. Assembling took minutes, and the mechanism itself is quite big.

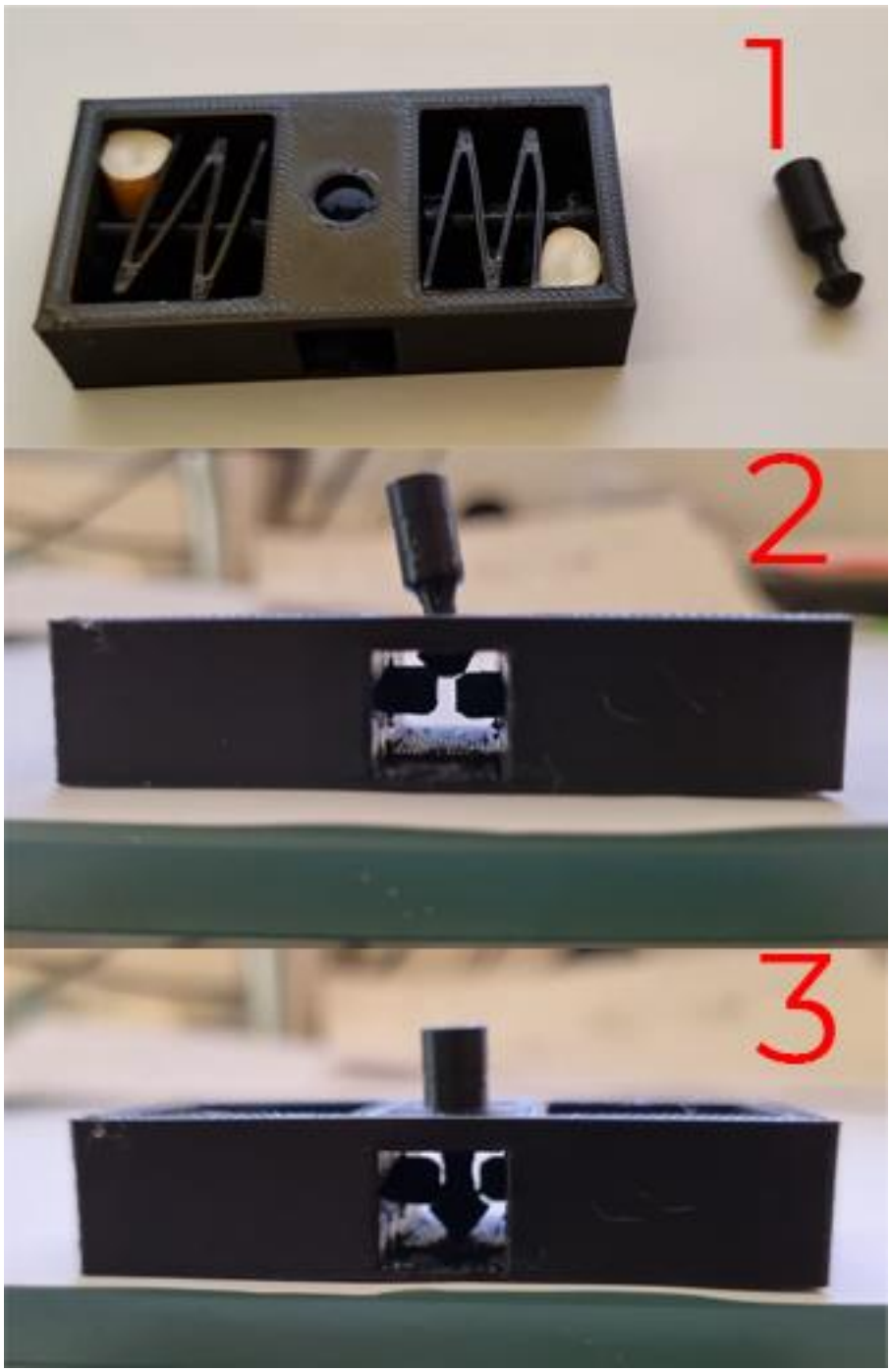


Figure X: 3D printed prototype of working principle

The fact that the moving mechanism is located in the Base is undesirable, since a broke part would be difficult to replace

Reverse – Mechanism in Feet.

In the arms industry a solution to the aforementioned problem, moving parts in the base, is found. To attach a shoulder strap, sling, to weaponry a quick attach and detach mechanism is developed. The mechanism is tested with a pulling force of 200 to 400 pounds. In figure X the working principle of the mechanism can be seen, which is the exact opposite of the previously, in figure X, proposed design.

Figure X: Quick Attach/Detach mechanism used in the Arms industry, including mounting attachment.

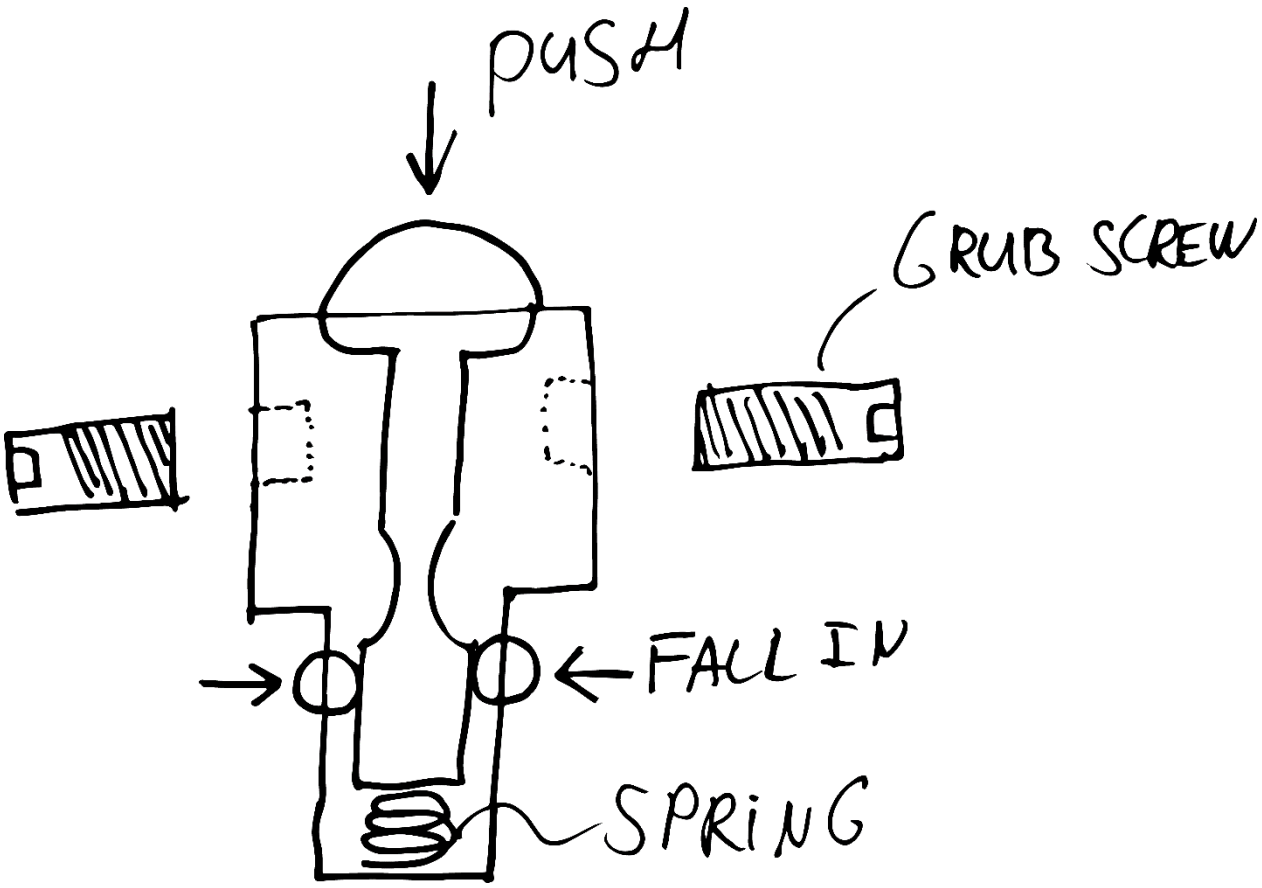


Figure X: By pushing the top button, the balls can fall in. Releasing the button the spring keeps the pin, and therefore the balls, in place, locking it in place.

Figure X: The same mechanism with, however the mounting attachment is replaced by an insert, making it easy to integrate in the Base.

Do’s

- Easy to use
- Mechanical Connection
- Reusable
- Clamping force regulated via spring design

Don’ts

- (semi) Moving parts in base
- Safety on the other side.

Lock-Line

Connection type: Form/Mechanical connection

The Lock-Line concept is based on the product developed by Lok-Line USA. Lok-line developed a set of products, resulting in flexible arms, that can be positioned by the user. The arms can be shortened and elongated by adding or removing parts.

Figure X: Flexible arm, available with multiple accessories.

The Lock-Line concept utilizes the coupling mechanism developed by Lok-Line. In the Base a negative space is created, in which the ball, attached to the Building Block, falls.

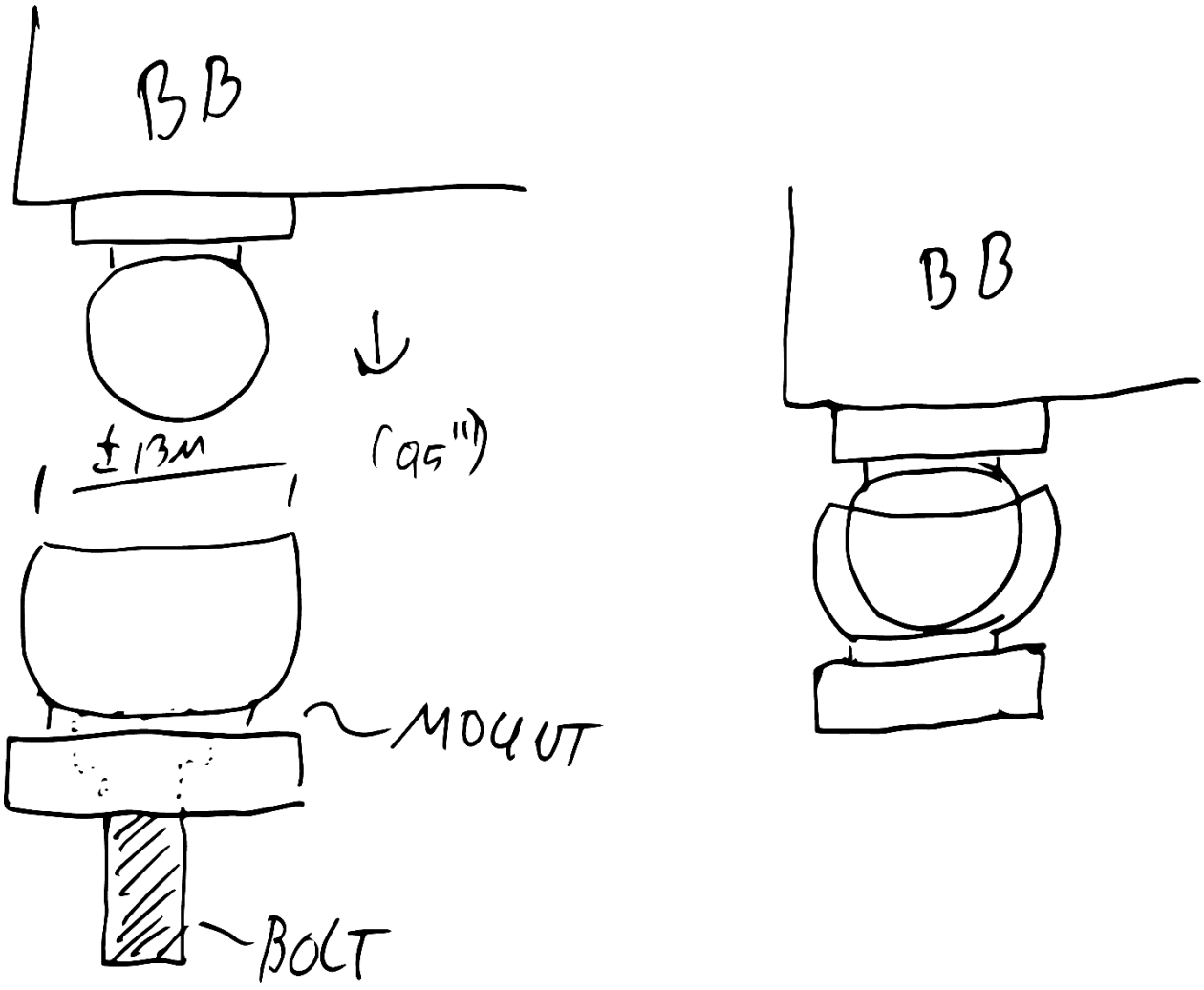


Figure X: Ball attached to Building Block, gets pushed into negative space(mount)

Do’s

- “Off the shelf solution”
- No moving parts

Don’ts

- Designed for other application

Magnetic

Connection type: Magnetic

Magnets are used for multiple applications in the Hifi market, first of all in speaker drivers and to hold speaker grills in place. A new usage can be seen in figure X, where they are used to hold aesthetical details in place.

Figure X: In the Cambridge Evo, All-in-One series, magnets hold the wooden panels in place.

The Magnetic concept is based on the similarly named magnets. A grid of magnets is placed into the Base, to which the building block magnetically can connect.

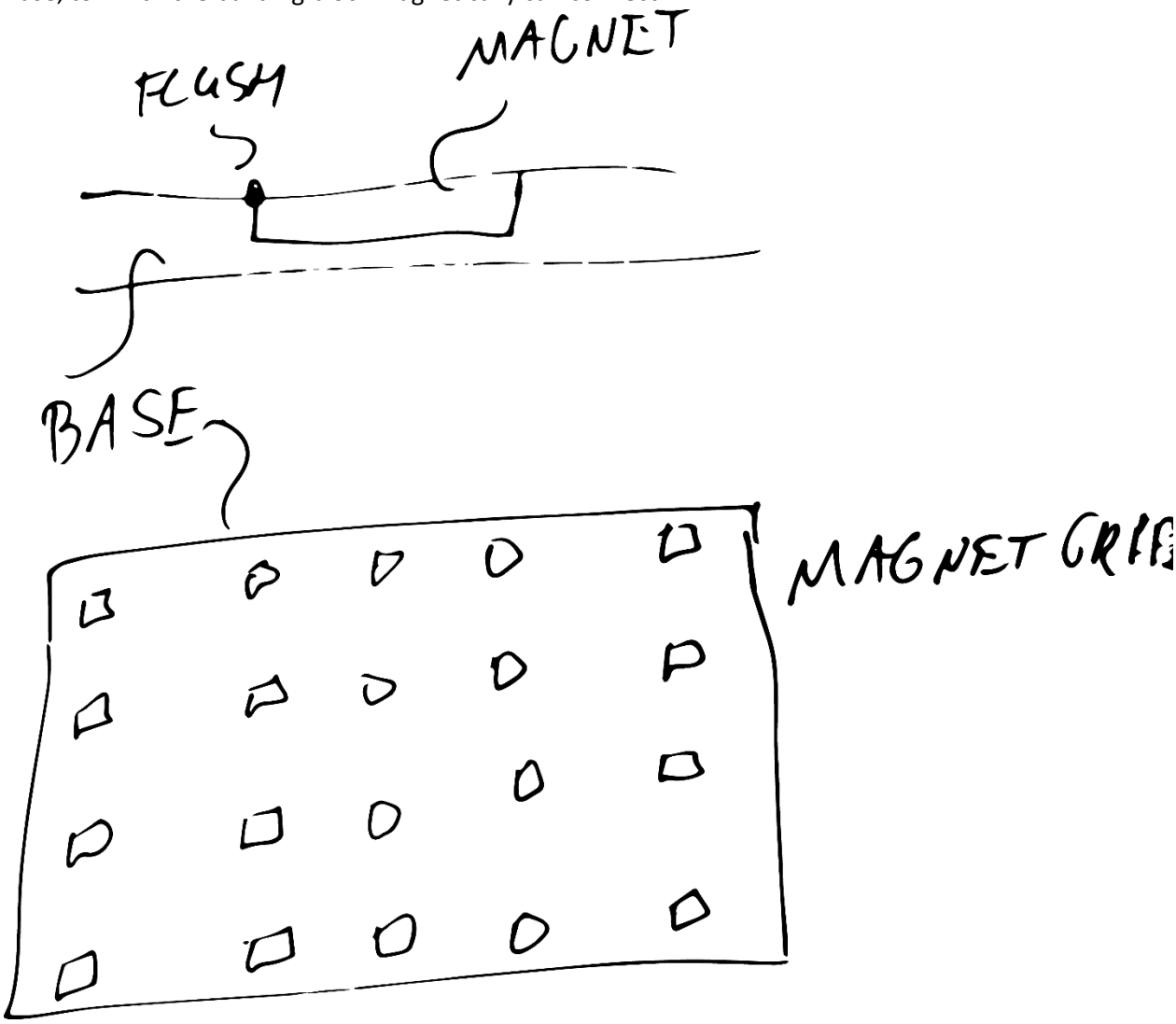


Figure X: A magnetic grid can be invisible to the user, by covering them in an additional layer of some sorts.

Benefits:

- Invisible Connection
- Easy to use
- No tools required

Drawbacks:

- Magnets lose their magnetic force over time
- Magnetic fields can have a negative influence on sound quality
- No mechanical/form connection, might not be able to hold the weight.

Row Lock

Connection type: Mechanical connection

Row Lock is based on a mechanisms found in optician stores, the display stands for (sun) glasses. These stands are equipped with a system that can lock and unlock all sunglasses at once. By integrating a similar mechanism in the Base, all Building Blocks could be unlocked at once.

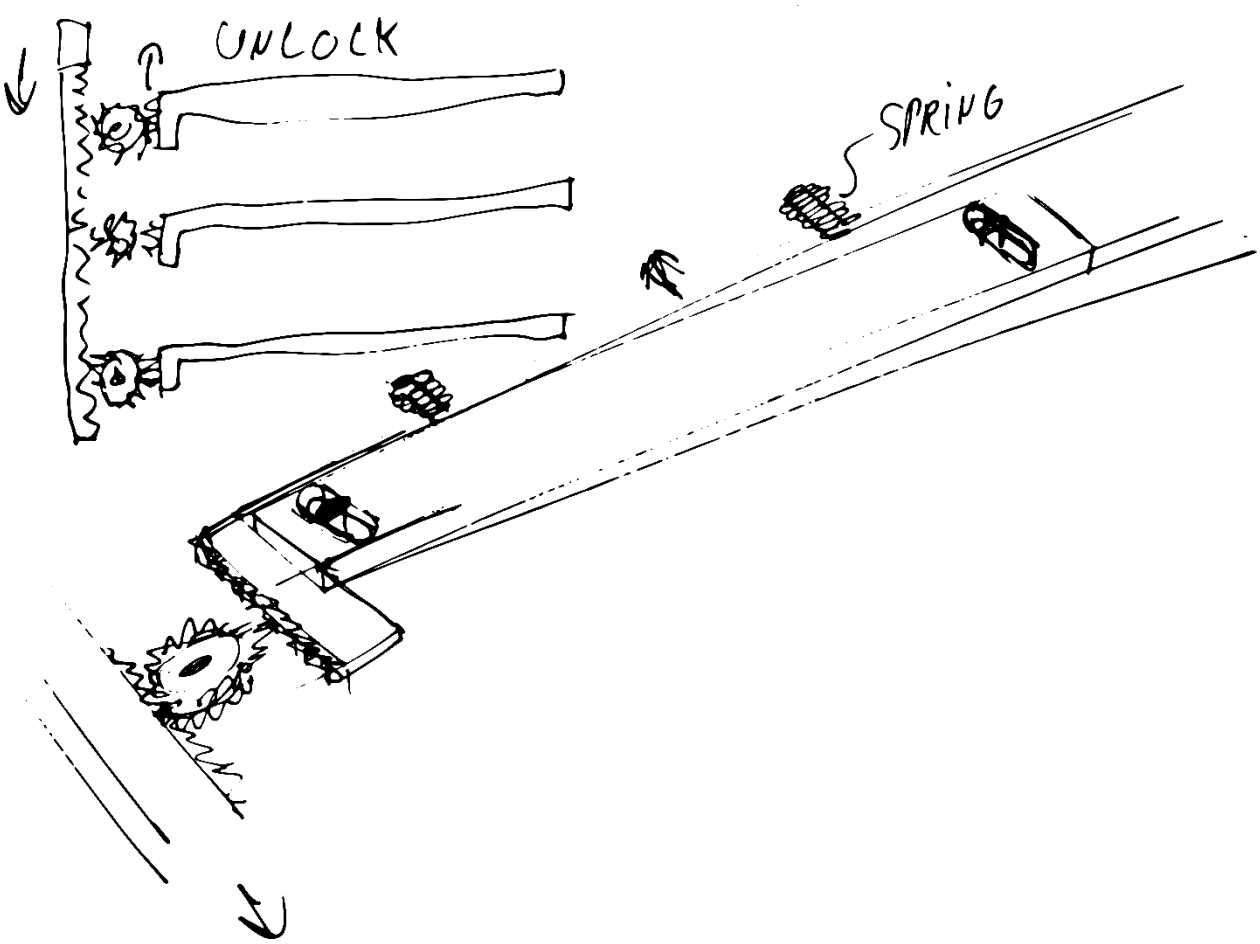


Figure X: The direction of movement is inverted via a gear, guiding slots keep the motion linear. Springs push the mechanism back to its origianl position.

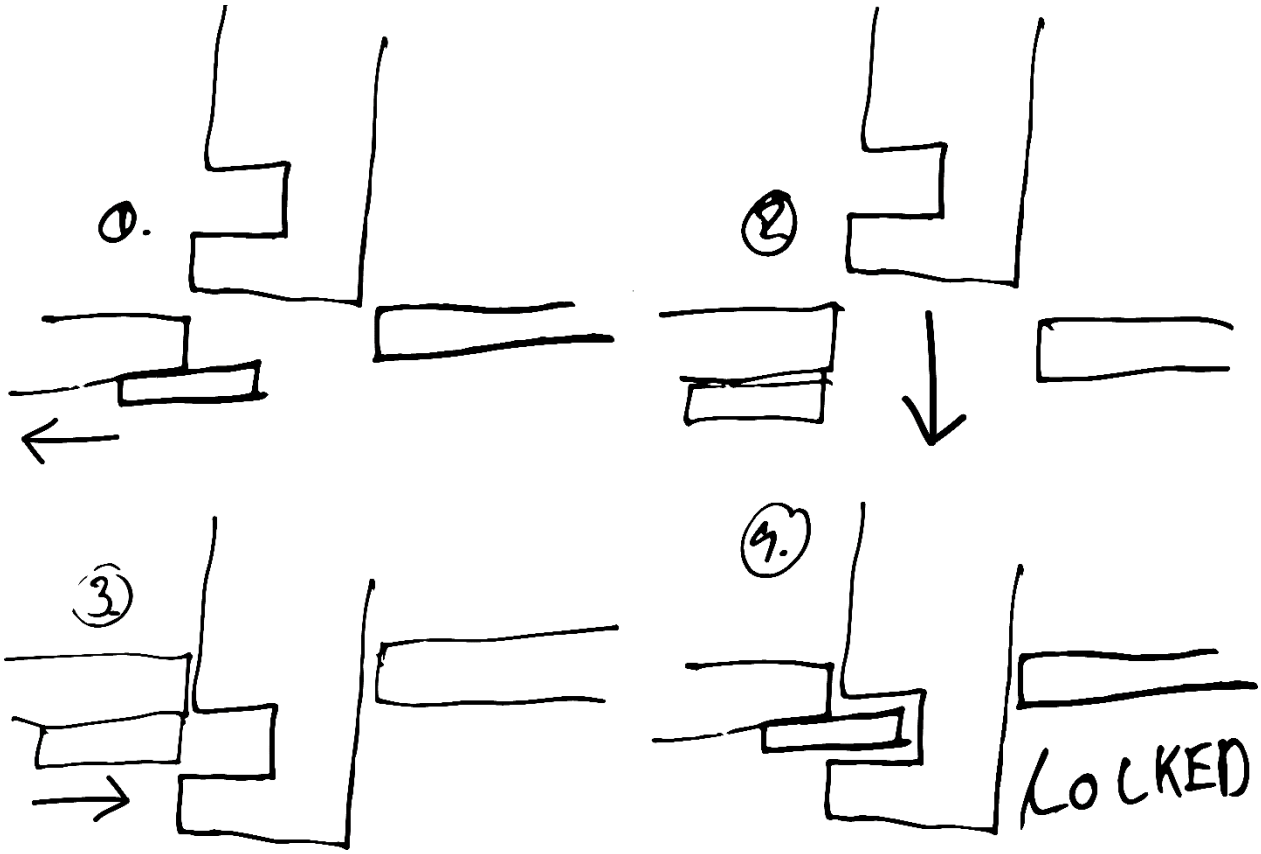


Figure X: Feet with a notch are pushed through the base, moving the mechanism aside, after which it is locked in place by the springs.

The working principle is tested, using a simplified 3D print. The mechanism, which can be seen in Figure X, workes, even on this small scale and unsuitable production mechanism.

Figure X: The mechanism worked partly, the surface roughness and scale of the gears made it move, but not linear.

Benefits

- Installation and removal from one side

Drawbacks

- “Complex” Mechanism
- Moving parts
- “Expensive”

Click Finger

Connection type: Mechanical connection

Attached to the bottom of the Building Blocks are Click Fingers, variants of snap fittings. The Click Fingers slide through holes in the Base, where the Base compresses the Click Fingers. If they are pushed all the way through, the Click Fingers expand again and lock the Building Block in place. To remove the BB (Building Block) a tool needs to placed around the Click Fingers, compressing them, after which it can be pulled out.

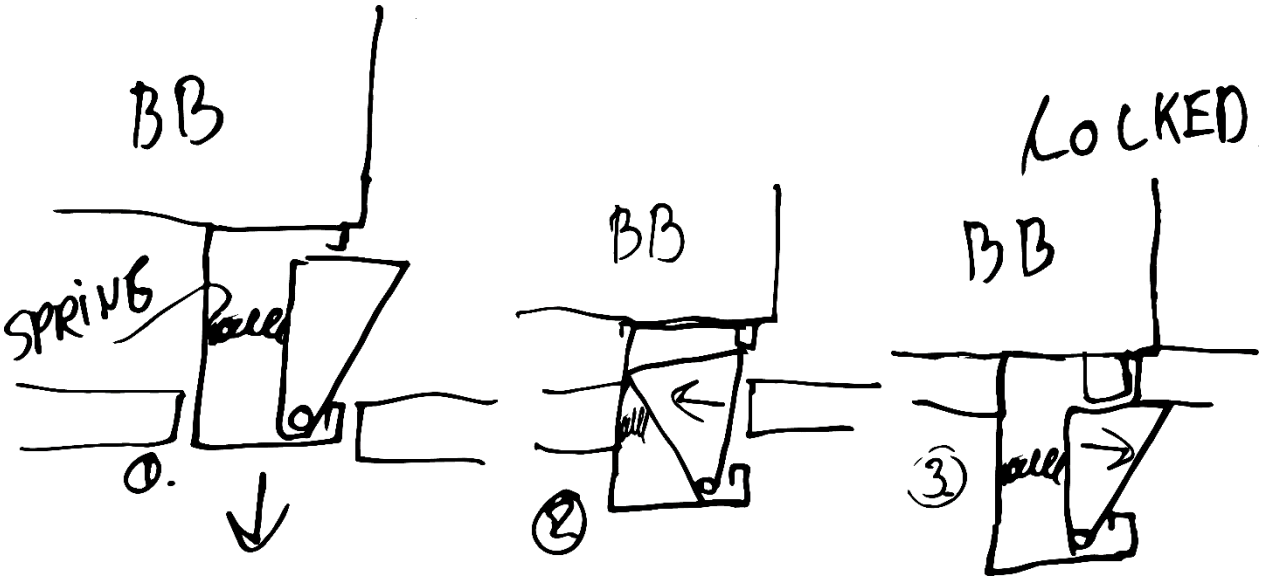


Figure X: 1. Click Finger in rest. 2.Click finger compressed by Base. 3. Click Finger locks BB in place.

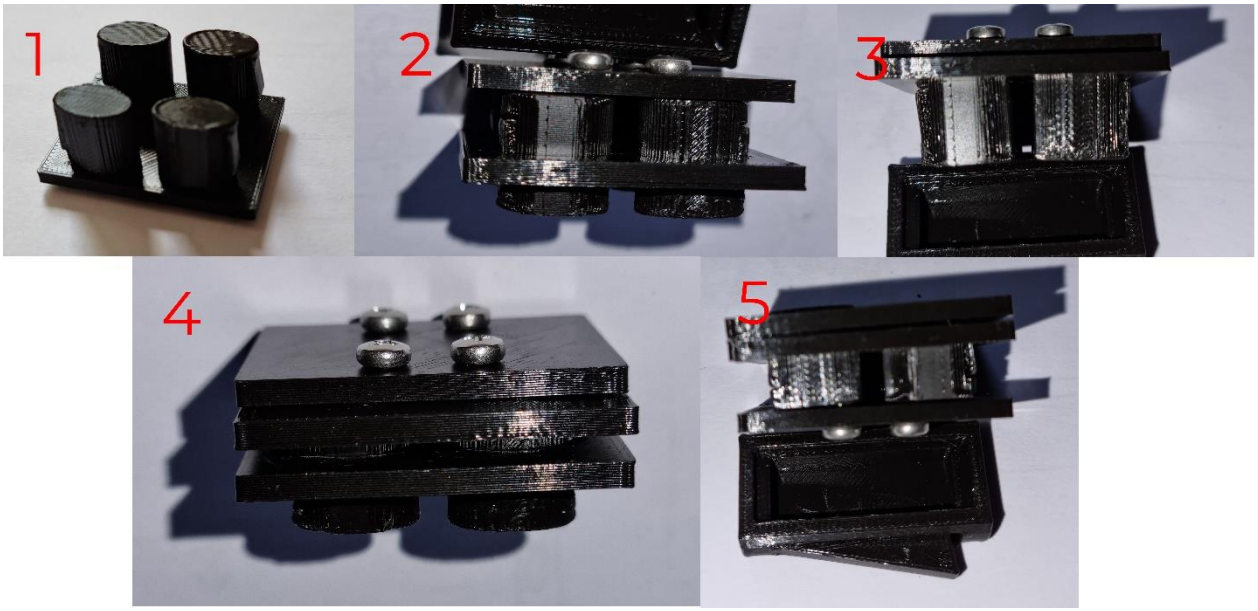


Figure X: 1, Four feet attached to the BB. 2, Pushing the feet through the Base. 3, Pushed all the way through the fingers expand again. 4, A tool is placed around the found pushing the fingers back in. 5, The Building Block can be pulled out of the Base.

Benefits

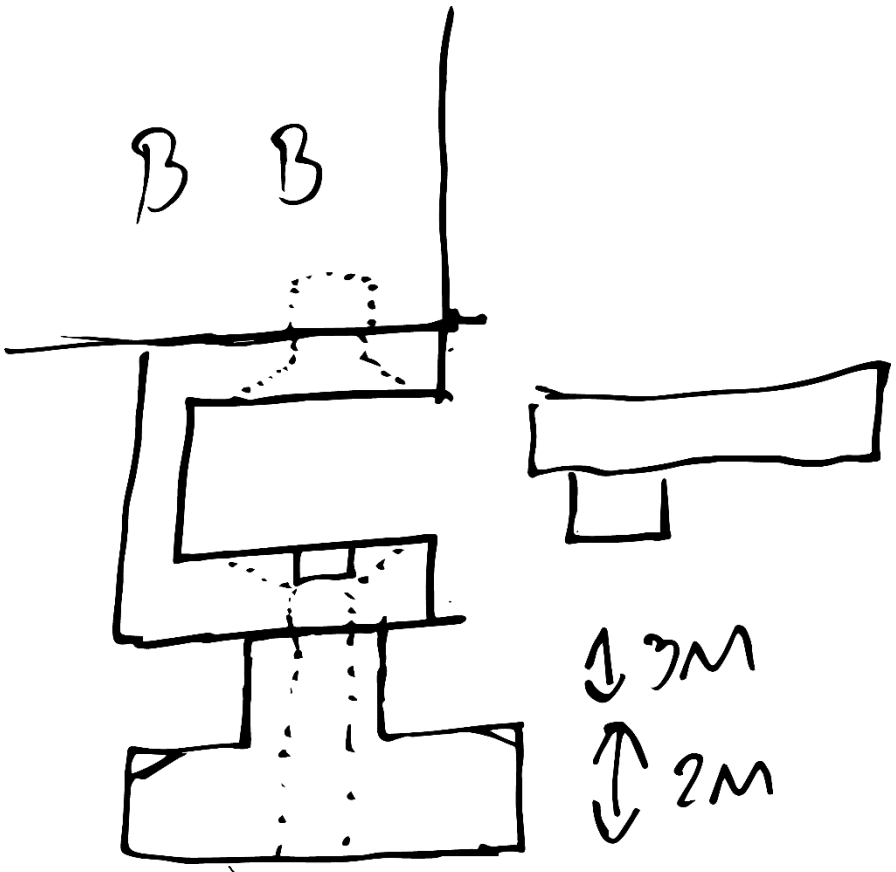
- Mechanical connection
- (Semi) moving parts in the feet (compliant mechanism)
- Shape of the feet can ensure correct positioning.

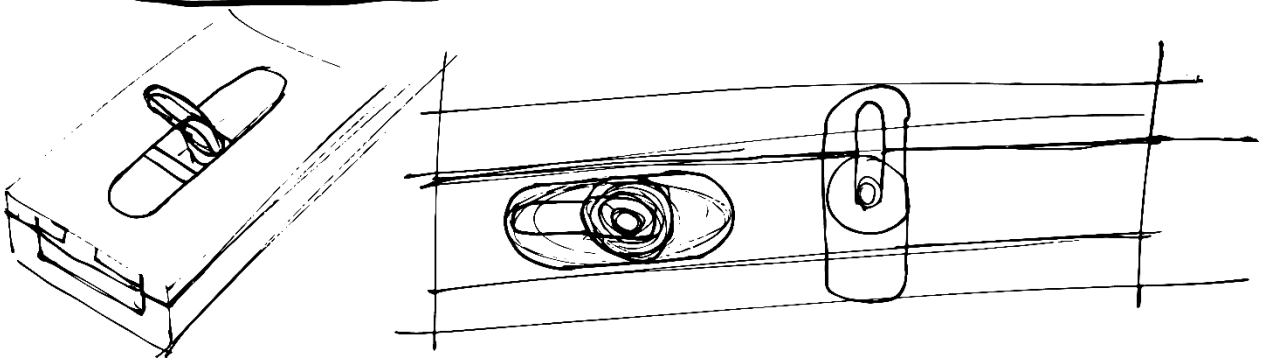
Drawbacks

- Feet can Jam because they move
- Might be difficult to remove the BB's
- Tool needs to be placed from the bottom.

Rotating – Standoff

The Rotating – Standoff concept is also derived from the arms industry. This is the mechanism used to attach the mounting plate, as can be seen in figure X. A quarter turn locks the feet in place.





Benefits

- Existing, tested, mounting mechanism.

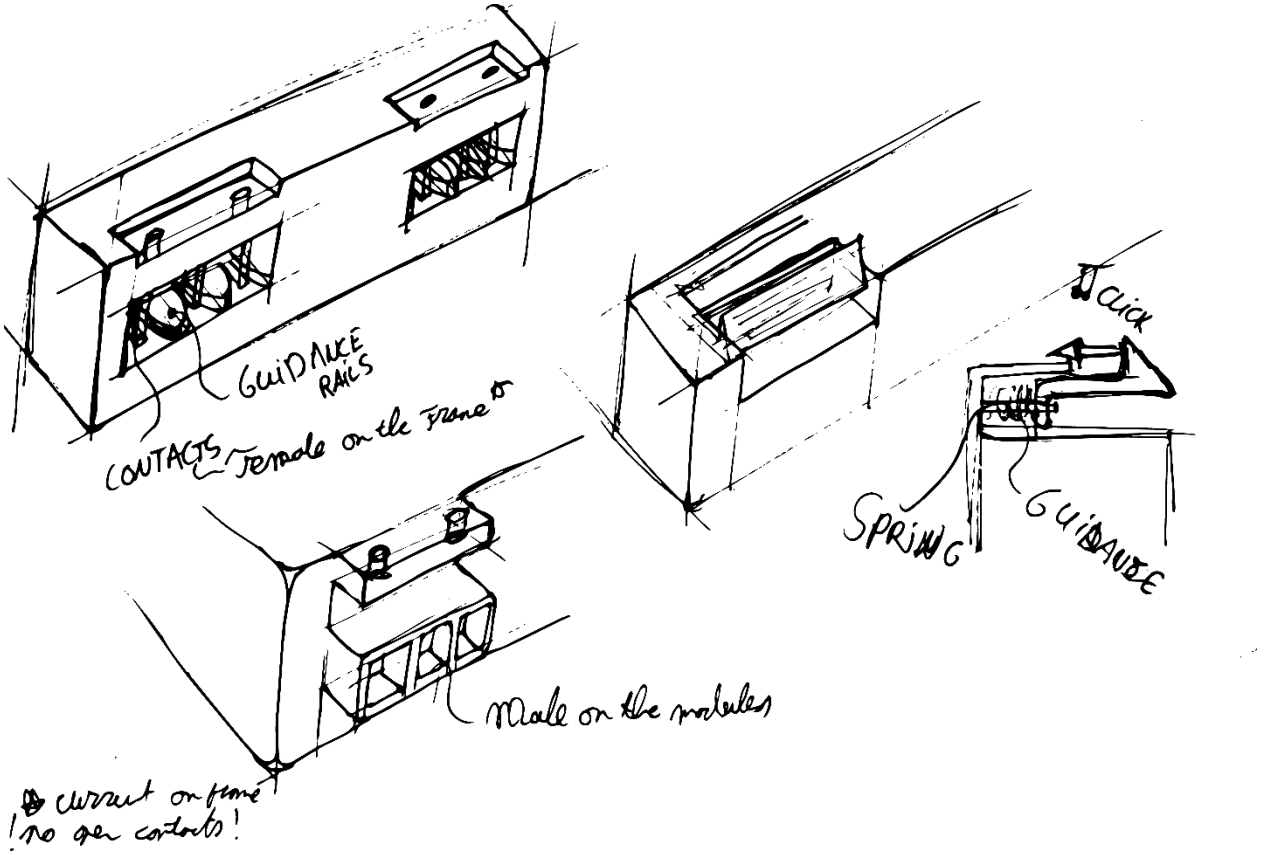
Drawbacks

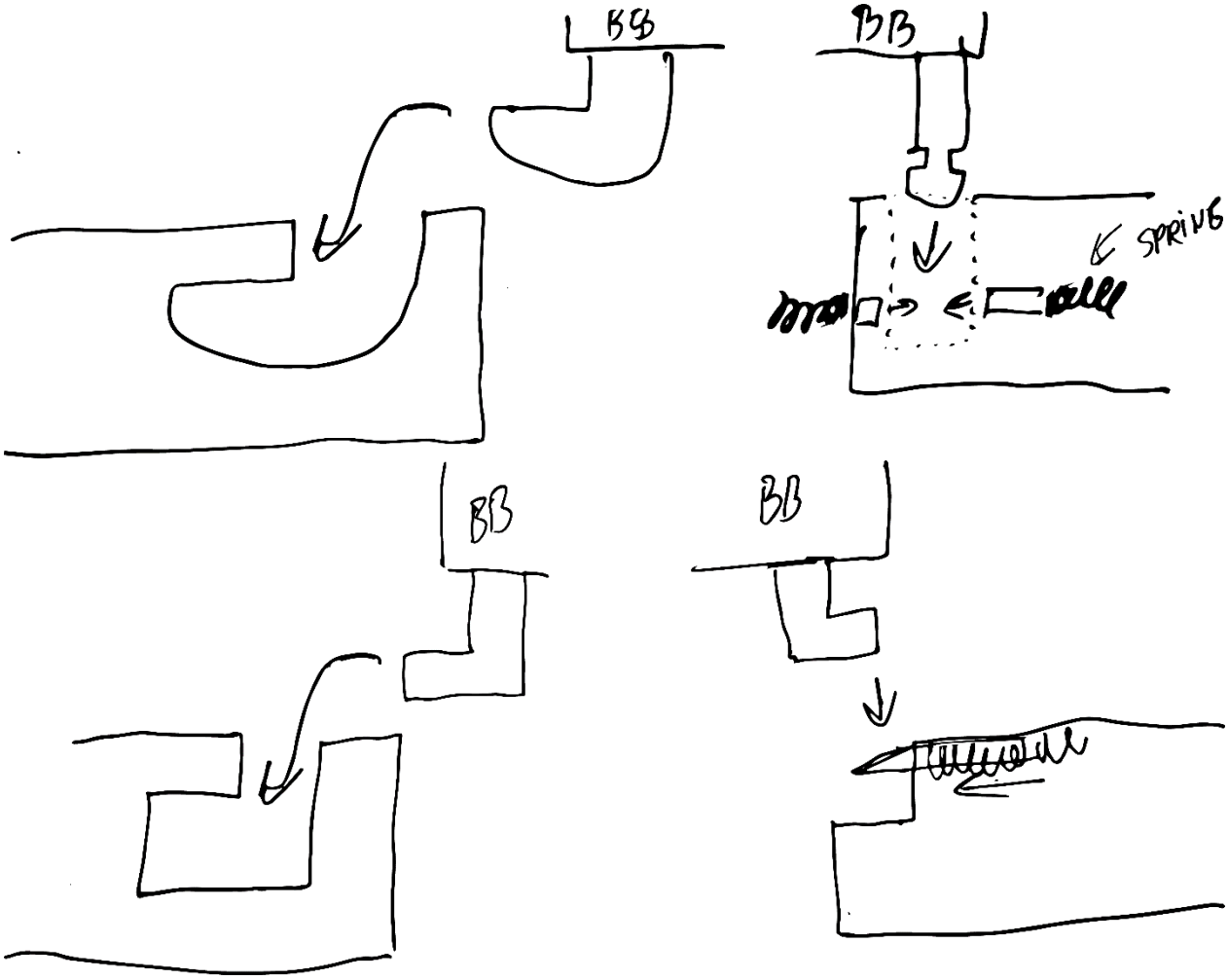
- Space between the Building Block and the Base is inevitable.

Fit & Click

Connection type: Form + Mechanical connection

This concept uses a combination of a form connection and a mechanical connection. First the form connection is made, followed by the mechanical connection. Combining the two methods reduces the number of moving parts and improves its durability.





Benefits

- Combination of Form and Mechanical connections
- Easy installation

Drawbacks

- Moving parts.

Requirements

0. Sowieso
    a. The Building Blocks can be installed with view from one side
    b. Installing and replacing is as easy as possible.
        i. No specialised tools needed (soldering e.g.)
        ii. There is no (advanced) technical knowledge needed during installation

    c. The user should not be able to harm themselves or the equipment while building

    d. The connection should be reusable
        i. No one time fasteners are used.

1. User installable/replaceable.
    a. The Building Blocks can be replaced/removed with a (supplied) tool.
2. Sustainable
    a. The connection should be durable
    b. One connection type should be used for all Building Blocks
3. Functionality
    a. The Building Block – Base connection should not influence sound quality
    b. The connection method should not hinder other operations
    c. Moving parts
4. Space required
    a. Space needed around the Building Block?
    b. All parts should fit within the outer dimensions (490*370mm)

Requirement	Y/N	Wish
Environment		
PCB's must be separable from enclosure		PCB separable without prior knowledge
Production techniques should have minimal environmental impact		Production techniques have a positive impact
Module materials have to be recyclable		Module materials are reusable
Materials used comply to EU regulations		Materials used dont have to be tested by EU
Permanent joining of different materials should be avoided where possible		
Hazardous materials should be avoided where possible		
PCBs should be separable from their enclosures		
Cables should be detachable from the PCB		Cables are not soldered to the PCB
For the HiFi solution to be sustainable the transformers should be easily accessible, reusable and replaceable.		
User		
Functions		
The HiFi solution should be able to have a preamplifier		The preamplifier in the HiFi solution can be upgraded
The HiFi solution should be able to have a power amplifier		The power amplifier in the HiFi solution can be upgraded
The HiFi solution should be able to have a DAC		The DAC in the HiFi solution can be upgraded
The HiFi solution should be able to have a streamer		The Streamer in the HiFi solution can be upgraded
The HiFi solution shoud have a sufficient power supply		The Power supply in the HiFi solution can be upgraded
The HiFi solution should be able to have a standby power supply		The Standby power supply can be changed
The HiFi solution should be able to have the option to play radio		The HiFi solution can play radio via the internet or DAB+
The HiFi solution should be able to have the option to stream music		The HiFi solution can stream in High Resolution
		The HiFi solution can be equipped with Bluetooth
The HiFi solution should be able to have analog inputs		The number of analog inputs can be expanded
The HiFi solution should be able to be fitted with a phono stage		The phono stage is available at different levels of performance
The sound of the HiFi solution can be adapted		The HiFi solution should be able to have a mono/stereo feature
		The HiFi solution should be able to have a balance feature
		The HiFi solution should be able to have bass/treble correction
The HiFi solution should be able to have a Headphone Amplifier		The headphone amplifier is upgradable
FM radio will not be included in the HiFi solution, because it will be turned off in the foreseeable future.		

Usage	
The HiFi solution should be controlable using a software platform	The HiFi solution is controlable using multiple software platforms
The HiFi solution should have the option to be controlled via physical buttons	All functionalities can be controlled using physical buttons
The HiFi solution should have the option to be controlled using a software application	The HiFi solution can be controlled using an app and physical buttons
The HiFi should be able to communicate to the user if something is wrong	The HiFi solution can communicate via an application
	via the front of the unit
	point where the defect is located.
Modules must be replacable by user	Easy
Modules can be connected by user	
User nog limited in combinations	All functions possible in one system
Amplifier should be designed for a home setting	
Amplifier should be designed for music enthusiast	
System should fit different price levels	
Parts of the system should be upgradable	The whole system is upgradable
IMS must fulfil the needs of the user	IMF fulfills the wishes of the user
Technology	
Minimize module dimensions	
Maximize PCB acceptance	
Critical components should be easy to replace	All components are equally easy to replace
Amplifier must be powered by 230V	
System should have an OFF switch (not standby)	
Vibrations should be restricted, dampened (trafo)	
PCB's have to fit inside set modules	
Module status must be communicated to user	
Modules should accommodate different components (component = dac \\ phono \\ streamer)	
The HiFi solution should have the option to be equipped with multiple power transformers	
The Power transformers should not influence each other	
The HiFi solution should be able to accomodate power amplifiers with different power outputs	
The HiFi solution should be able to fit power transformers that fit the power amplifiers	
The cooling capacity should be sufficient for the power amplifiers	

The analog inputs should be close to the preamplifier section		The analog inputs cannot be closer to the preamplifier section.
The HiFi solutions fuctions should be available at atleast two levels of performance		All functions are available at multiple levels of performance
The HiFi solution should be economically viable for manufacturers		
The HiFi solution should meet governmetn regulatiosn		
Reusable connections should be used where possible		reusable connections are minimized
Removal of critical parts should be as easy as possible		Critical parts can be removed with only readily available tools
The usage of Loctite should be minimized		Loctite is not used
Soldered connections should be accessible		Soldered connections are minimized
Power cables should be removable		Power cables have an external connector
HiFi solution should be able to implement future developments		
Dimensions should have inner dimensions of 5*5 to 16*16		
Emty space is minimized		
Electromagnetic interference should be minimized		Electromagnetic interference is prevented
Rectifier replacement should possible		Rectifier replacement is as easy as possible
Heat dissipation should be sufficient		Heat dissipation is optimal.
The HiFi solution should be able to stream using an existing streaming architecture		The HiFi solution should have a hardwire off switch to save the stand by power supply
Design		
Base needs to withstand time		
Aesthticaqlly pleasing		Adaptable design
The HiFi solution should have a front that is changeable		The front of the HiFi solution can be personalised to be pleasing to look at
The HiFi solution should be usable in the living room		The HiFi solution is usable in any room
The functions of the HiFi solution should be expendable		The functions of the HiFi solution are upgradable
The HiFi solution should at least have one physical button		
The HiFi solution should have a dark colour		
Crucial parts placement should be guided by clear use cues		parts cannot be placed incorrectly
The use of one time fasteners should be minimized		One Time fastners used are readily available
		No one time fasteners are used.
The use of readily available replacement parts should be maximized		Only readily available replacement parts should be used.

The use of readily available replacement parts should be maximized					Only readily available replacement parts should be used.
Assembly time should be minimized					
Disassembly time should be minimized					
The amount of soldering required to disassemble should be minimized					Disassembly requires no soldering
Rectifiers should be accessible					Rectifiers are all in one location.
Disassembly steps to get to crucial parts should be minimized					Crucial parts are assessable without disassembly
Fasteners, fixings, nuts and bolts should be accessible					Fasteners, fixings, nuts and bolts are accessible without removal of other parts
Correct placement of the power transistors should be inspectable					Placement of power transistors cannot be incorrect.
The risk of a short between a power transistor and their heatsink should be minimized					A short between a power transistor and their heatsink is not possible.
Moving parts should be accessible					Moving parts are accessible a minimum number of steps.
The number of moving parts should be minimized					No moving parts are used
Glass fuses should be in a fuse holder					The fuseholder is easy to access.
Reduction of Elco's lifetime by heat should be minimized					Reduction of Elco's lifetime by heat is not possible.
Speaker relays should be accessible					Speaker relays are accessible in a minimum number of steps.
Internal temperatures should be minimized					Internal temperatures are as low as possible
The usage of soldering is minimized					No soldering is required
If used the stand-by power supply should be accessible					The stand-by power supply is accessible in a minimum number of steps.

Program of Requirements

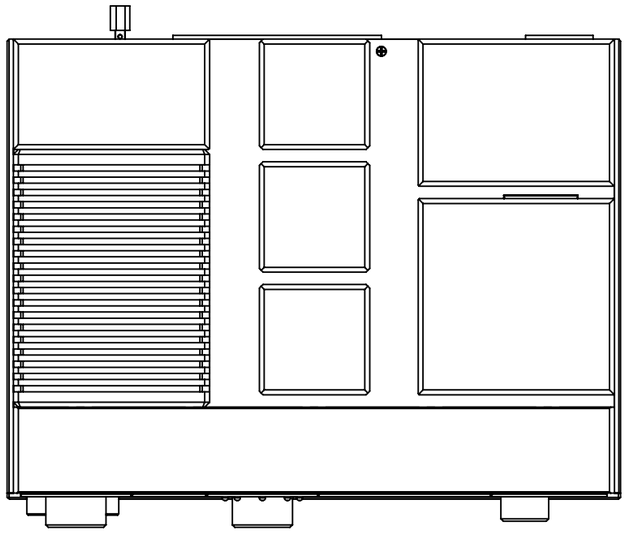
Requirement	Use Y/N	Wish
Environmental		
Upgrading minimizes environmental impact		
User		
System should be save to work with		
Modules should be replaceable by proffesionals		Modules are replacable by user
Visible side should be adaptable to user preferenes. (Aesthetics,(colour, material, buttons))		
Module status can be communicated to proffesional		Module status is communicated to user.
Reliable		
The functions of the HiFi solution can be expended by a Professional		The functions of the HiFi system can be expended by the user.
The functions of the HiFi solution can be expended by a Professional		The functions of the HiFi system can be expended by the user.
The HiFi solution should be able to meet the requirements of the users		
The HiFi solution should be usable in a retail context		
The HiFi soltuion should be repairable in an economic manner		
The HiFi solution has to be usable in a store setting		
Assembling and disassembling should only require a clear view on side of the HiFi solution		Assembling and disassembling can be done without a clear view
Technical		
System should have the option to have buttons/ and or app		
Amplifier should allow easy upgrading of components		
Module connections should be accessible		
Modules should be accessible		
Modules should be repairable by experts		
Connector of module must be set by manufacturer or retail		
Modules are repairable in an economic viable way		Modules repairable in a cheap way.
The functions of the HiFi solution should be expendable		The functions of the HiFi solution are upgradable
Design		
The Front of the HiFi solution should have customiczation options that fit user preferences		
The HiFi solutions front should allow personalisation		The whole exterior is customizable
The front of the HiFi solution should be owned by users, since it expresses their personality.		

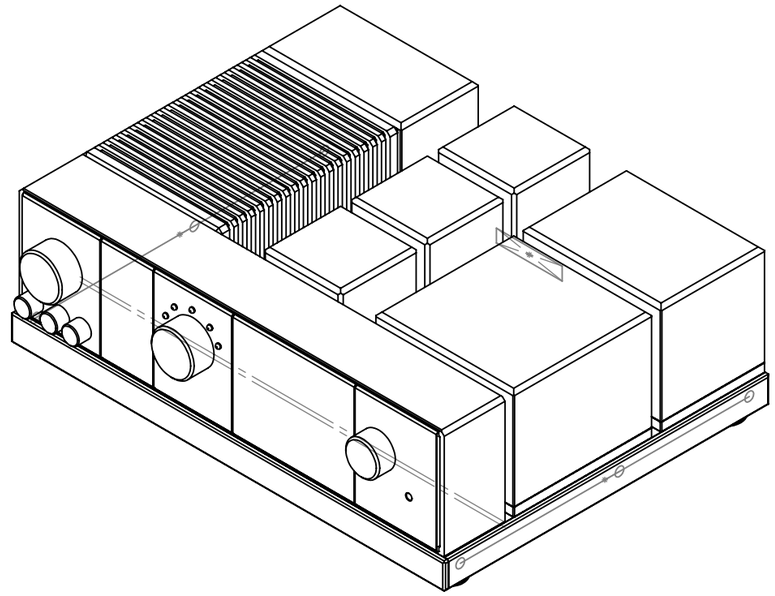
Program of Requirements

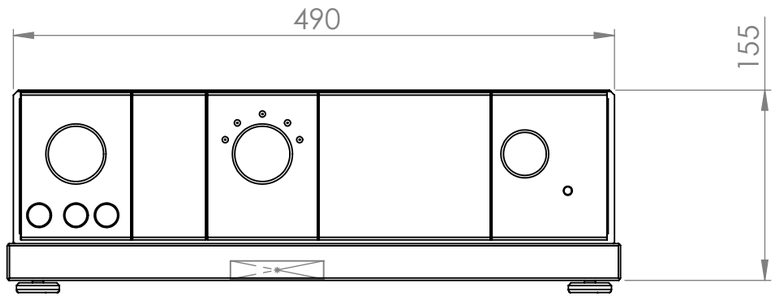
Discard

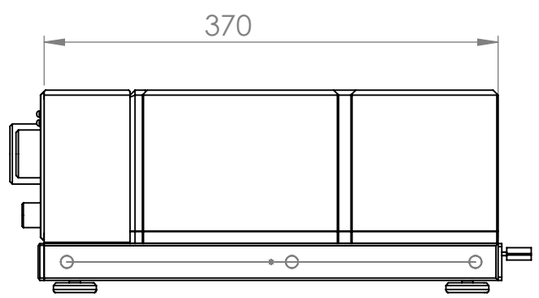
Requirement	Y/N	Wish
Environment		
PCB's must be separable from enclosure		PCB separable without prior knowledge
PCB easily seperated from enclosure		
Materials used should be recyclable – reusable		
Modules should be reusable		
User		
The level of specialized knowledge needed for repairs should be minimized		No specialized knowledge needed for repairs.
Technical		
Module enclosure must be producible with standard production techniques		
Safe		
Design		
PCB removal should be as easy as possible		PCB removal requires only “household” tools
Dissasembling should result in a minimal number of loose fastners, fixings, nuts and bolts		Disassembly results in no loose fastners, fixings, nuts and bolts.

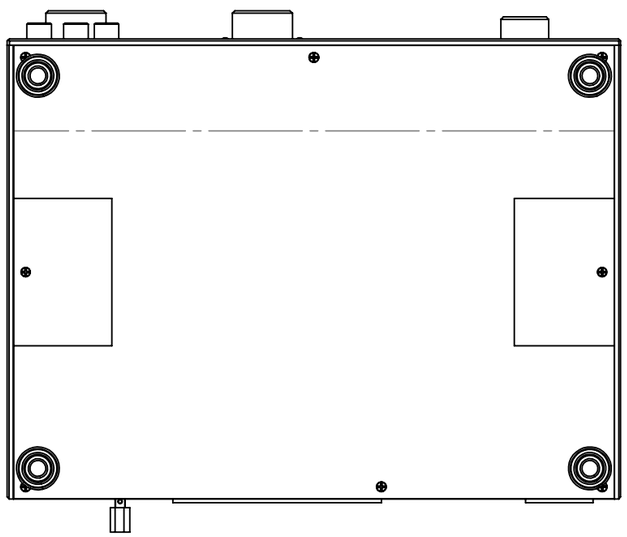
Appendix S - Technical Drawings – Overall Dimensions



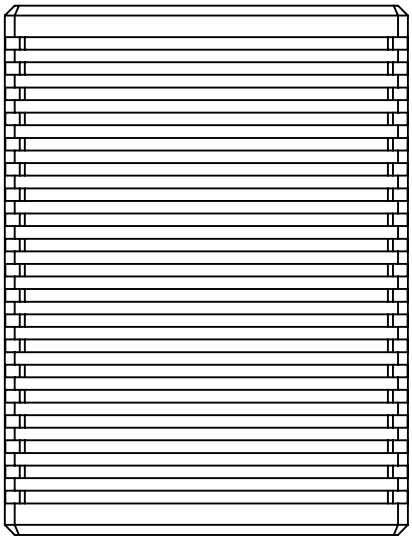


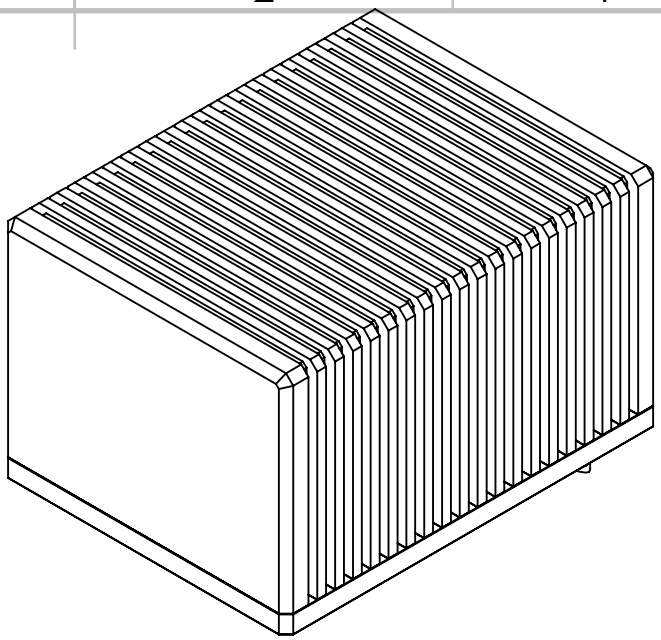


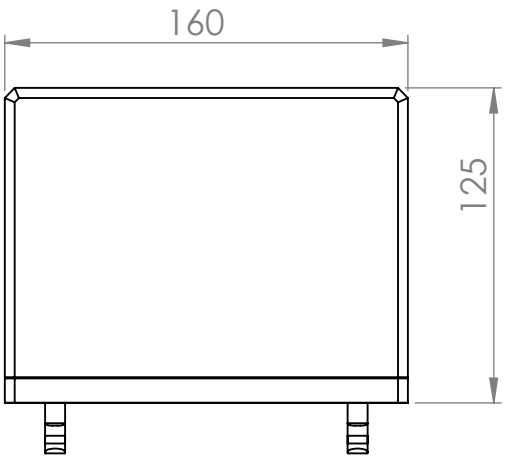


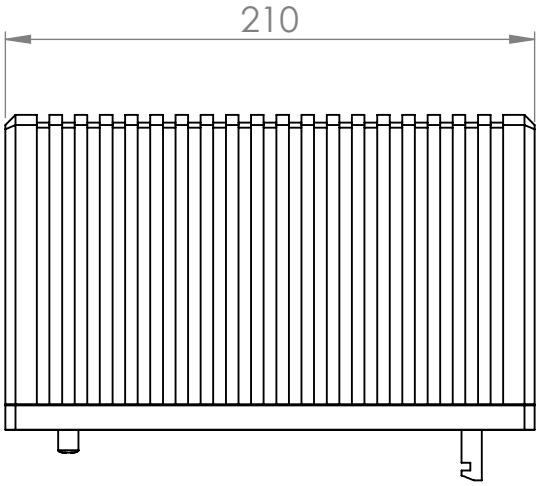


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A3
						Model B New Assemblies	
				WEIGHT:		SCALE:1:5	SHEET 1 OF 1









UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:

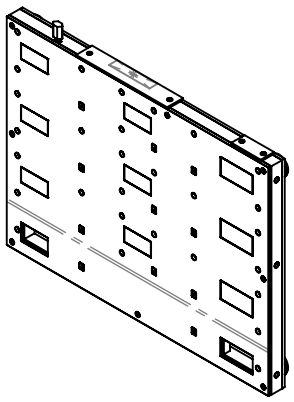
WEIGHT:

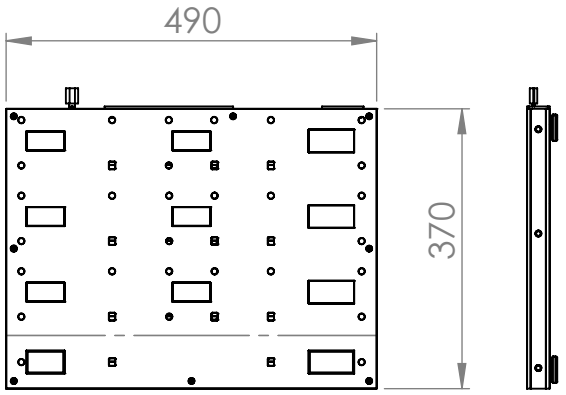
TITLE:

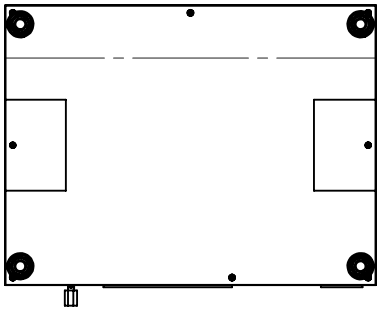
DWG NO. 210x160 Enclosure A4

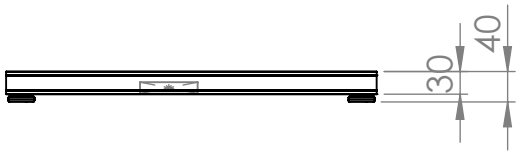
SCALE:1:3

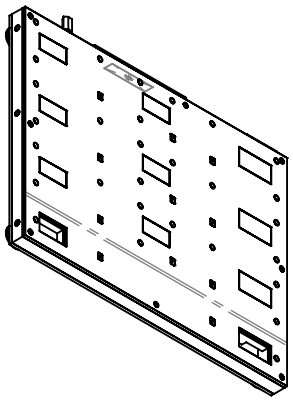
SHEET 1 OF 1



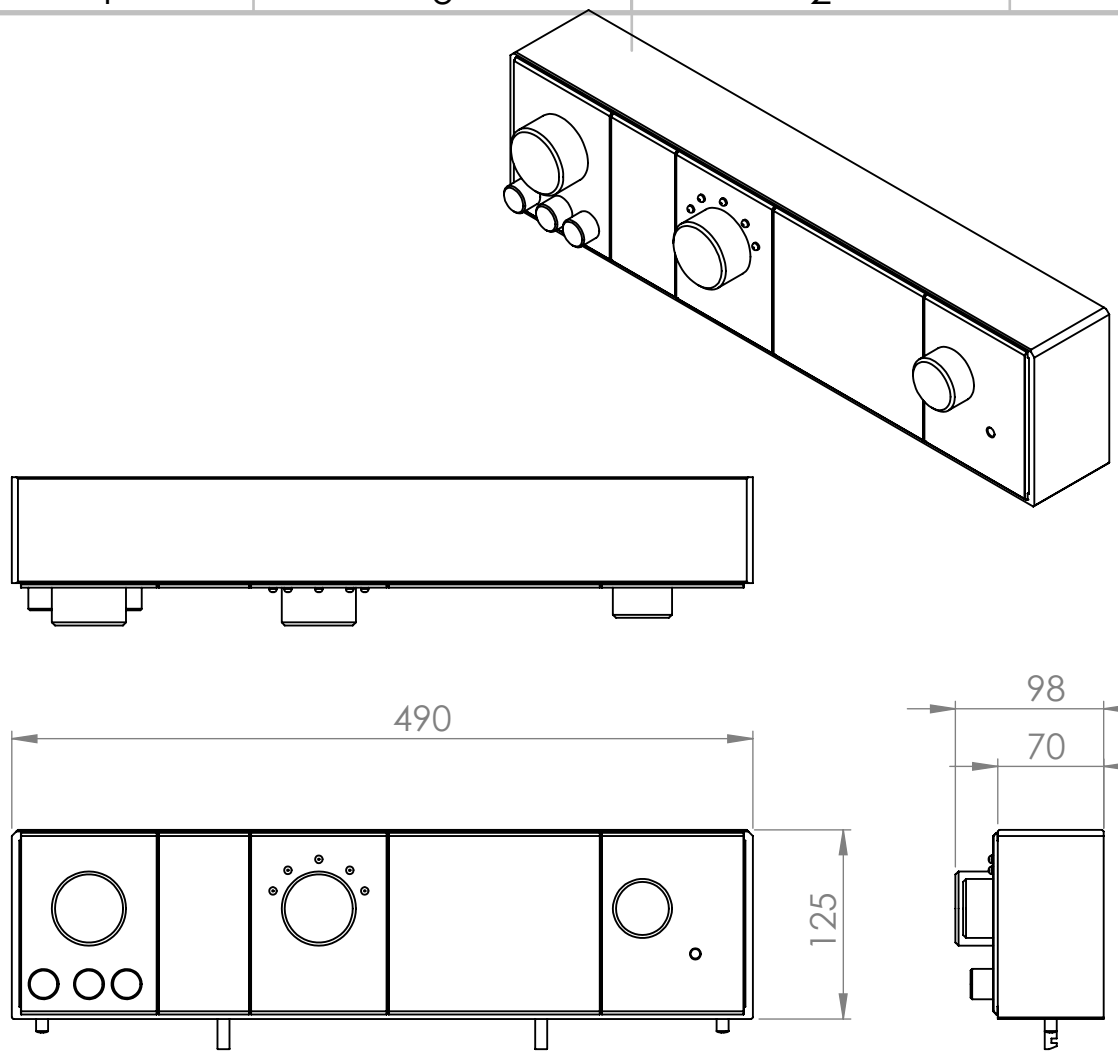








UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A4
						Model B Base	
				WEIGHT:		SCALE:1:10	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

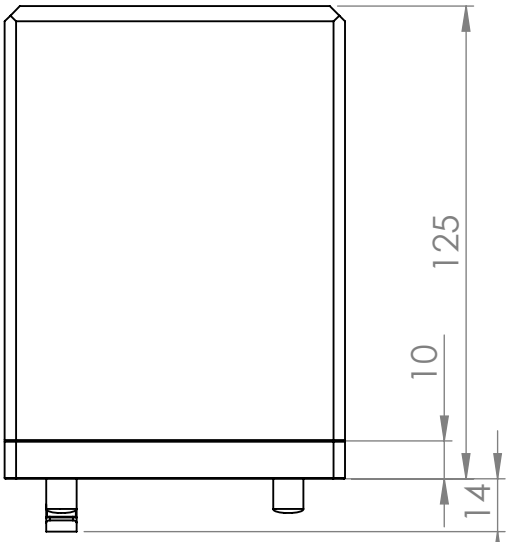
DWG NO. User Interface Ass

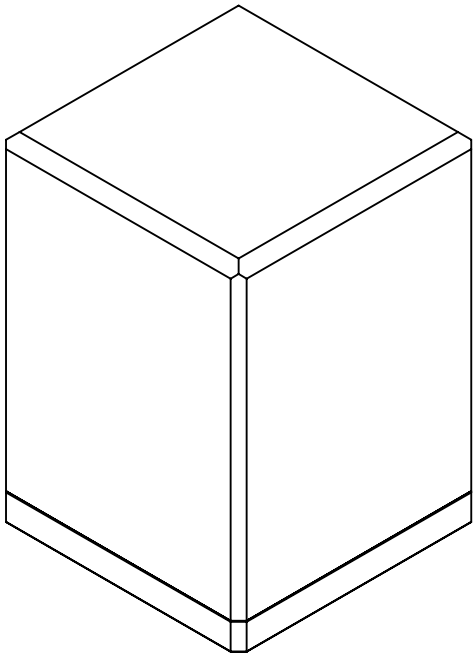
A4

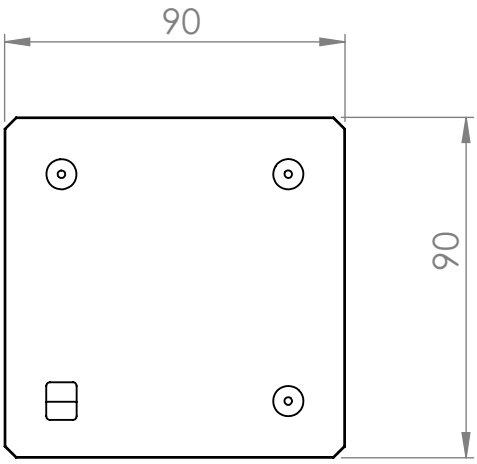
WEIGHT:

SCALE:1:5

SHEET 1 OF 1







UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

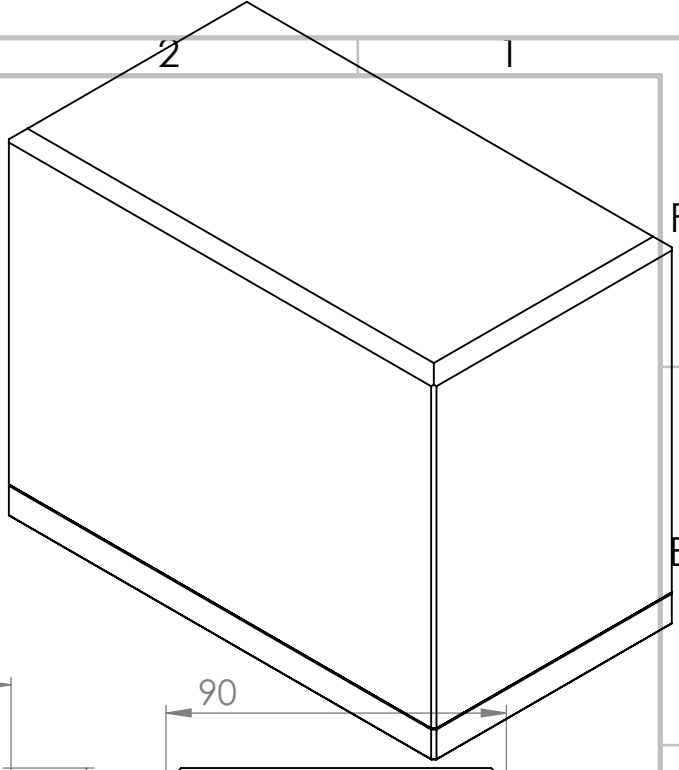
DWG NO. 90x90 Row lock

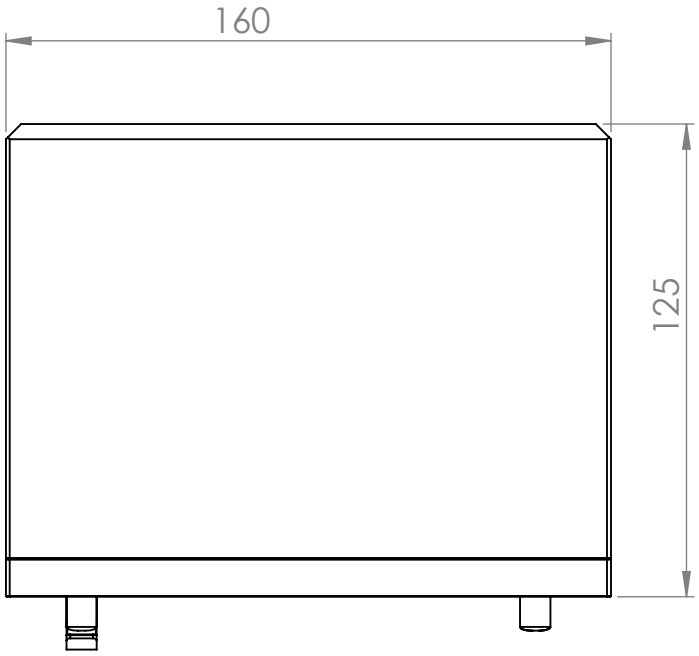
A4

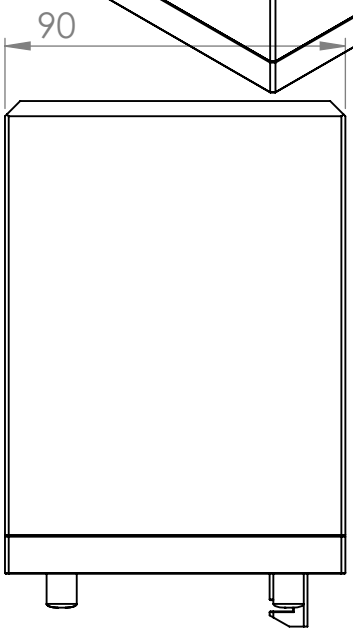
WEIGHT:

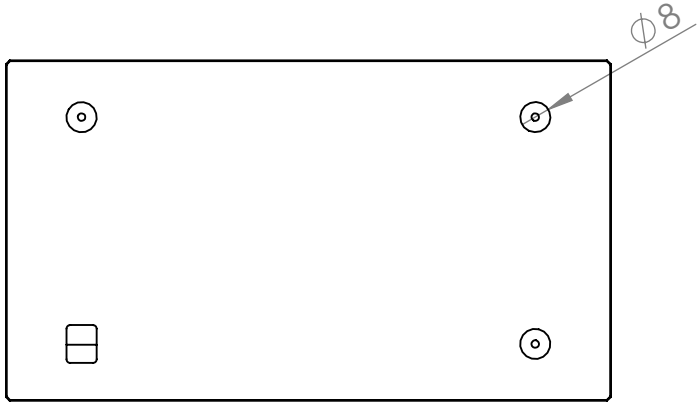
SCALE:1:2

SHEET 1 OF 1









UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

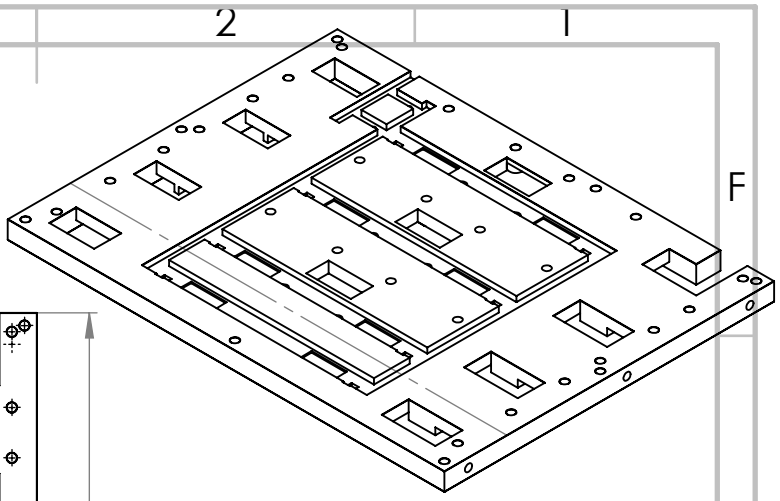
DWG NO. 90x160 Enclosure

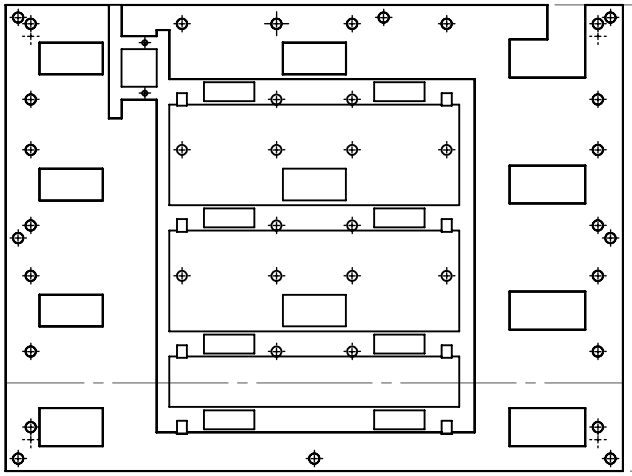
A4

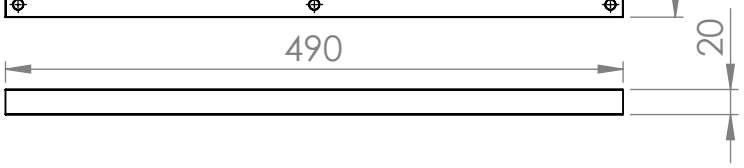
WEIGHT:

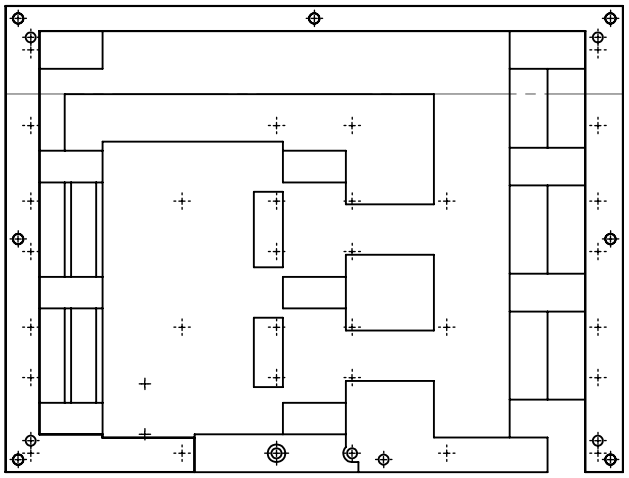
SCALE:1:2

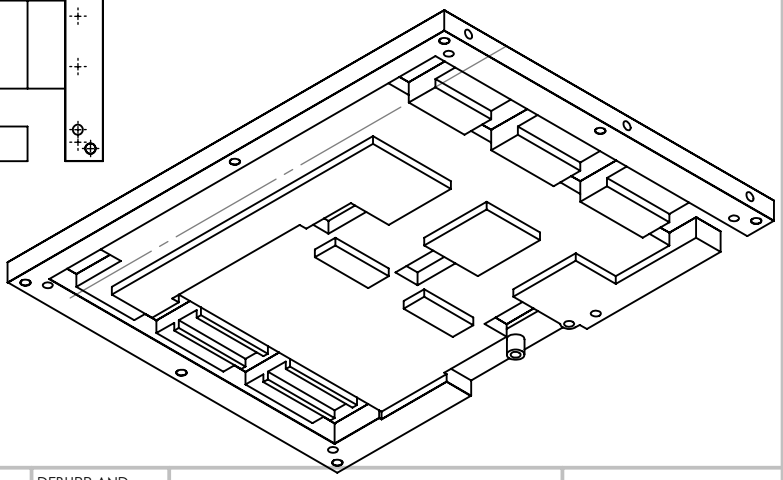
SHEET 1 OF 1











UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A4
						Bottom Base Model B V2	
				WEIGHT:		SCALE:1:6	SHEET 1 OF 1