Designing a Compact Computer Case

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Abstract

This report has been written for the course MF2019, *CAD 3D-modeling and Visualization*, during the fall semester of 2017. The assignment was to make use of newly acquired CAD skills in the software *Solid Edge ST9* by either reverse engineering or creating a new design. The author particularly wanted to learn more about the sheet metal, harness (wiring), and rendering functionality. The goal was to design a minimalistic and reasonably silent compact computer case that could fit full-size enthusiast hardware.

Multiple existing computer cases were investigated in order to find cost-effective design solutions and to gain an understanding of what is possible to manufacture. Different kinds of computer cases and the components they house were researched, including which form factors should be followed.

The result is a computer case with outer dimensions below 300x350x400 mm that can fit an ATX motherboard, multiple GPUs (up to 310 mm in length), a 175 mm CPU cooler, a 240mm radiator, one 5.25" optical drive, one 3.5" HDD, and two 2.5" SSDs. It is designed with positive internal pressure in mind, caused by a 200 mm intake fan and 120 mm exhaust fan.

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1 Introduction

This report has been written as part of the evaluation for the Royal Institute of Technology course MF2019: *CAD 3D-Modeling and Visualization*.

1.1 Purpose

The purpose of this assignment is to learn more about complex CAD-modeling in the *Solid Edge ST9* environment. The assignment specifies that the student can choose to reverse engineer an existing product or design their own. I decided to go down the route of designing a compact computer case for modern hardware, while investigating how real cases have been designed and manufactured for inspiration.

1.2 Personal goals

I specifically want to learn more about designing products which incorporate sheet metal and wiring, which I believe will be very applicable for designing mechanical systems, which should be useful for the Master's Degree in Mechatronics that I am pursuing. I also have an interest in computer hardware, so a computer case seemed like a product that is sufficiently limited in scope in order to analyze all the parts of, without having to simplify too many parts. I also want to be able to use this project for my portfolio, which could be used to build a one of a kind computer case in the future. It would also be great to learn more about how to visualize products before they have been manufactured, or for marketing purposes, by rendering and animating them.

1.3 Solid Edge Environments

In order to achieve my personal goals, I will focus mainly on mastering the following *Solid Edge* environments:

- Sheet metal
- Harness (wiring)
- Rendering (using *Keyshot*)

1.4 Delimitations

The project result will not be ready for manufacturing, even if the parts have been designed with specific manufacturing techniques in mind. The product is meant to work together with other system components, such a power supplies, motherboards, and fans. These models have either been imported or designed in limited detail, with the purpose of demonstrating the functionality of the assembled computer case.

2 Computer case design standards

The first step, before deciding on how to design the computer case, is to go through what requirements a computer case has to live up to, and how other models have been designed. As such, for this project, the best or cheapest solutions I find in existing cases will be incorporated into the design.

2.1 What is a computer case?

A computer case (or chassis) is in the simplest terms simply an enclosure in which to mount computer hardware such as the motherboard, power supply, and hard drives[1]. Due to the standardized nature of such components, it is important that the dimensions adhere to existing physical standards for mounting holes, etc. Especially for gamers, it is very common to choose an aesthetically pleasing computer case that also provides ease of access for upgrades and has good cooling capabilities.

The two most common case designs are so called tower and desktop cases. A tower case stands tall, like the name suggests, with a vertically mounted motherboard. A desktop case instead sits flat, often acting as a stand for the computer monitor. Other options exist, such as ultra compact NUCs, All-in-Ones (AIO), and home theater PC (HTPC) which usually limit what components can be installed due to their limited volumes.

Another important aspect of computer case design is to provide adequate ventilation for active cooling of the processor and any add-on graphics cards. This can be done by mounting fans in the case. It is also important that there is enough free space for the air to flow unrestricted; ideally without having to change directions, which can cause turbulence. It is recommended to keep any cables out of the way as much as possible through cable management. Cool air should be drawn in, and warm air should be expelled. In order to achieve this, it is recommended to place intake and exhaust fans on opposite sides of a computer case. Note that convection will lead to hot air moving upwards, which can cause a passive draft.

In order to limit the amount of dust build-up a popular method is to achieve positive pressure within the case. This can be done by having higher volume of air pulled in through the intake fans than the exhaust fans. Any differential pressure is equalized through any additional gaps or holes in the case. If a dust filter is fitted on the intake fans, all air is filtered, causing minimal dust build up. An another option is to cause negative pressure which leads to direct airflow and amplifying natural convection, although dust will find its way in through any gaps [2].

2.2 Computer hardware

For somebody who is new to computer hardware, a short list of the most common computer hardware, as well as common standard size factors, follows below:

2.2.1 Motherboard

The motherboard, sometimes shortened to ”mobo”, is a fairly large circuit board which connect all of the other components with each other. It normally houses the processor, random access memory, and the graphics card. Other components are connected through standardized cables. See the common sizes below in figure 1, with full dimensions for ATX available to read in the specification [3].

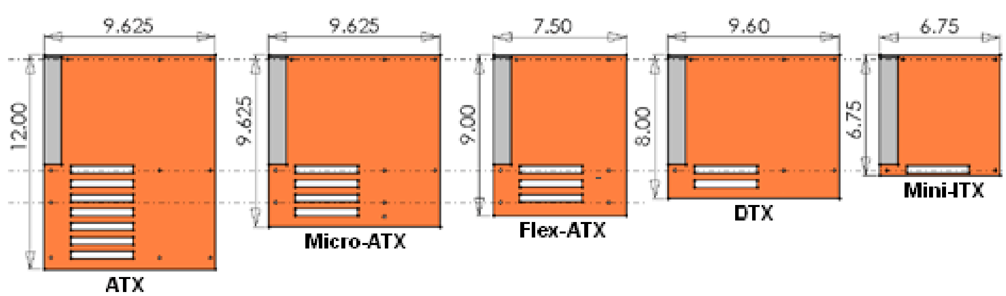


Figure 1: Various motherboard form factors. Dimensions in inches.

2.2.2 Processor and cooler

The central processing unit (CPU, processor) is the ”brain” in the computer, and can often generate around 100W of heat, which requires sufficient cooling. For example, the *Intel Core i7 8700K* has a thermal design power (TDP) of 95W [4]. The processor is placed in a specially designed socket. The CPU cooler attaches on top of this. The bottom of the cooler has a flat surface which conducts heat away from the processor, and usually on to a large heat sink. A fan then blows cool air through the heat sink, which allows the heat to dissipate, as shown in 2. The height, above the motherboard, of an air cooler is up to as much as 171 mm, according to Inet [6], although the most popular products seem to be up to 165 mm. This is an important dimension for deciding on the size of the computer case. Liquid cooling attaches in the same way, but pumps the liquid to a radiator with fans to very effectively expel heat.

Figure 2: Coolmaster Hyper 212 Evo CPU Cooler [5]

2.2.3 Random Access Memory

Random Access Memory (RAM) is used during run-time, and is cleared upon shutdown. The memory is fitted in slots on the motherboard, and the dimensions of these will not impact the design of the case, as the CPU cooler and graphics card will protrude more than the RAM. Most ATX motherboards support 4 or more sticks of RAM, while smaller mATX and mITX boards may only support 2 due to the limited space.

2.2.4 Graphics card

Computers use either integrated graphics, or dedicated graphics cards. Most gaming or workstations require a dedicated, stand-alone card. In modern systems, this card is installed to a PCI-Express slot on the motherboard, but may use more than one PCI-Express tab on the back of the case. Some computers also include multiple graphics cards. Inet [6], a popular Swedish computer hardware store, stocks graphics cards with lengths from 144mm to 325mm, with the most sold models within the span of 242-298mm. For extra long graphics cards, it is common for the power cables to protrude from the side of the card, rather than backwards. This adds on to the necessary distance between the motherboard and the side of the case, and needs to be addressed when designing a case, as shown in figure 3 below.

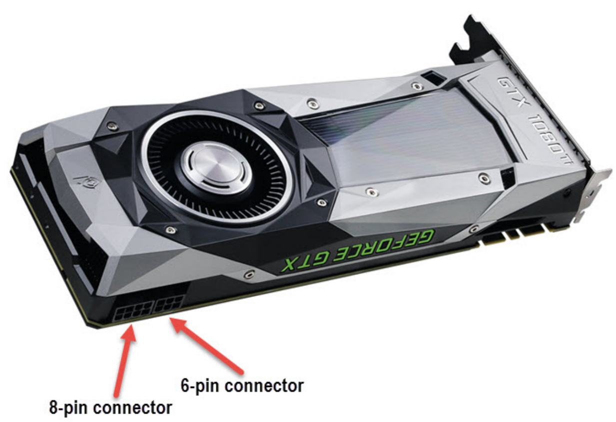


Figure 3: The *Nvidia Geforce GTX 1080 Ti* takes up two slots and has power cable connectors on the side.

2.2.5 Power supply unit

The power supply unit (PSU) transforms alternating current from a wall socket to useful direct current voltages for use within the computer. The most common form factor is ATX, which specifies a certain width and height, while the length varies. Inet [6] sells power supplies with lengths up to 225mm, while the most common models seem to be 140-180 mm long. Some PSUs are modular (removable cables, as shown in figure 4) while others may require a compartment to keep unused, non-removable cables. Power supplies are often cooled by pulling in cool air from a fan, and ejecting the warm air through the back of the unit, out of the case.

Figure 4: *be quiet! Dark Power Pro 11* 750W modular power supply

2.2.6 Storage media

The operating system, programs, and files are stored on hard disk drives (HDD) or faster solid state drives (SSD). Both of these types share common mounting holes, adhering either to the 3.5" or 2.5" standard. As time passes, more traditional 3.5" HDDs lose ground to the smaller 2.5" SSDs (and occasional HDDs). The power and data connectors are the same, following the SATA interface. Other alternatives exist, such as plugging into PCI-Express or m.2-connectors on the motherboard. Power users may need multiple storage units, while most users rarely need more than two drives with adequate storage space.

Figure 5: Size comparison of a 3.5” HDD, 2.5” SSD, and m.2 SSD.

2.2.7 Optical drives

While rarely used today, CD, DVD, and BluRay disc drives may be necessary for some tasks or when installing legacy programs. They all follow a standardized 5.25” form factor. Most units can be mounted horizontally or vertically.

2.3 State of the art

Even if nearly all components themselves are standardized, there is a wide variety of computer case designs to fit these components. Some cases are small, compact solutions that can provide adequate airflow, while others focus purely on aesthetics or holding as much hardware as possible. Other cases specialize on damping vibrations from the hardware or being very user friendly when installing hardware.

2.3.1 Enthusiast

For power users, who needs to fit the most powerful hardware, the case needs a large internal volume. This means that full-sized ATX motherboards are the go-to, with lots of space for a tall CPU air cooler, or even a massive water cooling system with several radiators, pumps, and reservoirs. Naturally, any truly hardcore gamer also needs multiple graphics cards to be able to play at their best. Pack in as many fans as you possibly can! Your computer is going to sound like a jet engine, but you may get a slightly cooler setup. And who doesn’t need 4 DVD-drives?

Jokes aside, there are usage cases where a true power user will need this amount of space, if they store vast amounts of data, mine cryptocurrencies, or conduct complex calculations. The *Corsair Obsidian 900D*, shown in figure 6 is a prime example. They are also usually very easy to mount components in, due to the sheer amount of space.

Figure 6: *Corsair Obsidian 900D* has enough space for the vast majority of power users. [14]

2.3.2 Compact

Among compact computer cases, most only fit mITX motherboards (see previous figure 1), which often do not offer as much functionality (for example, only supporting one graphics card and only having two RAM slots). Often, the limited space leads to compromises when fitting the PSU, GPU, CPU cooler, and any additional storage devices.

One example of a compact case that fits a lot of hardware is the *BitFenix Prodigy* [10] which has outer dimensions of 250x359x404 mm. A large part of the height is due to the ornamental design. It supports PSUs up to 160 mm (somewhat limiting the compatible selection), a single graphics card (double slots) with a maximum length of 320 mm (meaning that it fits nearly all GPUs), a CPU cooler with a height of 180 mm (most coolers are compatible), as well as plenty of storage media and a disc drive [6]. As seen in figure 7 almost half of the space is taken up by the storage media and the disc drive.

Figure 7: *BitFenix Prodigy* isometric and open view.

Other notable examples that suffer from the same limitations to some extent are the *Raijintek Metis* (190x277x254 mm, max GPU length of 170 mm, max CPU cooler height of 160 mm) [7], *Phanteks Enthoo Evolv ITX* (230x375x395 mm, max GPU length of 330 mm, max CPU cooler height of 200 mm) [8][8], and *Cooler Master Elite 110* (280x260x208 mm, max GPU length of 210 mm, max CPU cooler height of 76 mm) [9].

2.3.3 Designer

Some computer builders find it necessary that their case has a unique exterior, such as the options pictured below. This often leads to a larger total volume, especially if the design is not a traditional rectangular prism, but can sometimes include smart solutions for mounting hardware or rearranging it from the standard tower case layout.

One such solution, that is sometimes found in compact cases as well, is the use of PCI-Express risers, essentially a cable that connects a graphics card to the motherboard. This solution is used in the *Deepcool Tristellar* computer case [12], shown in figure 8, where the motherboard and graphics card are in different sections of the case:

Figure 8: *Deepcool Tristellar*'s unique shape is made possible by using a riser.

Other computer cases which feature eye-catching designs are not so different at all under the hood. Two example of this are the *BitFenix Portal* (figure 9) and *NZXT Manta* (figure 10). Under the hood, the case itself consists of a rectangular box made out of sheet metal. Additional functionality, such as extra fans with filters, water cooling radiators can be fitted to the outside of this basic box.

Figure 9: *BitFenix Portal* has a very clean and rounded exterior.

Figure 10: *NZXT Manta* features a bulky shape fitted on a rectangular skeleton.

2.3.4 Silent

Other users simply want to have a dead silent computer. Based on knowledge acquired during the KTH course *Design of Silent and Vibration-free Products* (SD1116), it is best to stop the vibration at its source, such as making sure rotating systems (such as fans) are well balanced and do not produce standing waves within the dimensions of the box. Naturally, this is hard to design for with a computer case, without knowing exactly what components will be used. It is not possible to completely insulate the computer either, due to the required airflow. Instead one has to passively stop vibrations from propagating further from the source.

This can be achieved by adding damping materials between components to mechanically dissipate the energy, lining the inside of the case with foams which disperse the waves and keep standing waves from forming (as used in figure 11), and limiting the number of openings from which sound can escape through the air [19]. Large areas of sheet metal set in motion can also generate sound. In order to combat this, useful methods include adding rigidity to the sheet metal by bending it or adding dimples (areas that have been drawn from the original level) or otherwise limiting the areas that can move as one. Using heavier (thicker) sheet metal requires more energy to set in motion, but also leads to additional material costs overall.

Figure 11: The silent *Fractal Design Define C* case makes use of absorptive foam on the side panel, several air filters, and arrays of holes to reduce noise.

2.4 Notable design and assembly choices

Before beginning the design phase of the case, I decided to investigate cases that I had physical access to in order to find out some common design practices. At the very least, I then know what is possible to manufacture, and might find some very clever solutions to problems. Some notable design solutions are highlighted below.

First off, all of the cases I found were based on a sheet metal frame. Contrary to what I first thought, several sides of the ”box” could be made from one sheet. A cheap and stable assembly method seemed to be to align two holes and use a rivet to keep the two flanges positioned, as shown in figure 12. The flanges themselves provide a lot of rigidity, compared to using flat metal sheets for the sides. Also note how little tabs with a raised bump help to exert pressure against the sides, which minimizes rattling against the main frame.

Figure 12: The corner is fastened using a rivet going through two overlapping flanges.

Another, apparently very common, practice is to offset fans from the grills through indenting the screw holes and raising the whole grill slightly. These keeps the fan blades from brushing against the case, which may cause unwanted noise and hindering the fan from working efficiently. Also note that this specific case is compatible with two fan sizes by providing multiple mounting holes.

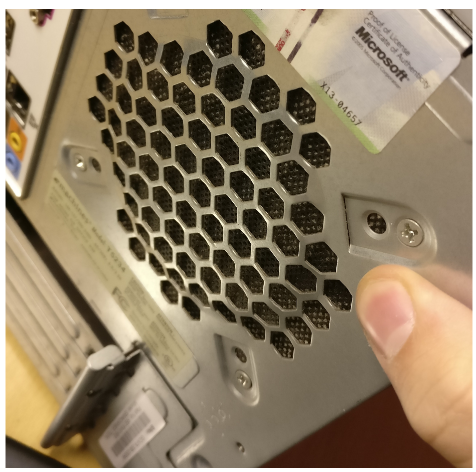


Figure 13: The grill and fan are kept well apart.

Another interesting design choice was to use raised dimples for the threaded ATX screw holes, instead of a small offset screw. I am not sure whether this cuts costs or not, but it seems like it can save a lot of time when assembling the case since it limits the number of individual parts. The ATX motherboard standard [3] specifies that a square area with sides of 0.4 inches (roughly 10 mm) is to be clear for standoffs. These standoffs are used to make sure that any motherboard tray structures have a clearance of 0.25 inches (6.35 mm) to the bottom planar surface of the motherboard PCB.

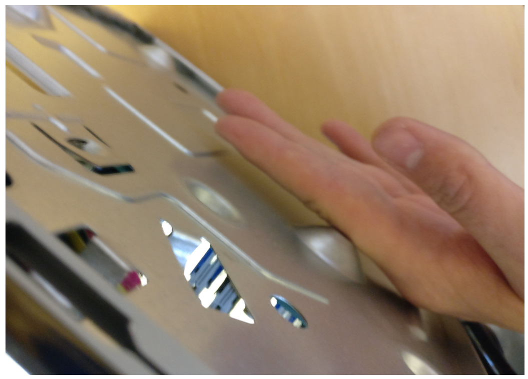


Figure 14: This case used dimples instead of removable standoffs to create a clearance to the motherboard.

One place that differed a lot between the investigated cases was the fastening of expansion cards, such as PCI-Express graphics cards. Some cases extended the back of the case past the motherboard's I/O-panel and the expansion card ports (which are in line), which lets the user attach the cards through an internal screw. While recessing the input ports may protect them from damage, it leads to a more complicated (i.e. more expensive) design overall. Some of the cheaper cases instead added an external fastener, as shown in figures 15 and 16 below. Note that the cards have to be pulled out perpendicularly to the motherboard, which requires some available space for mounting them.

Figure 15: One screw is enough to fasten multiple expansion cards. Behind the fastener, there is some space for the cards to be pulled from the motherboard.

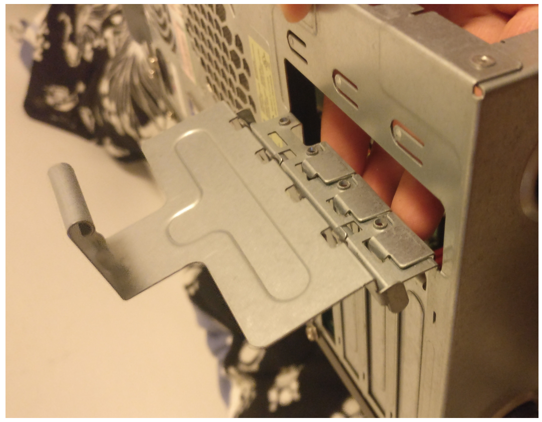


Figure 16: This screwless solution attaches around the edge of the frame, and keeps the cards in place by adding little pins instead of screws.

Another screwless solution was to fasten the DVD-drive by using a simple plastic rotary locking mechanism, as shown in figure 17. This same mechanism can be used for installing 2.5" and 3.5" storage drives as well.

Figure 17: Small plastic pins keep the DVD-drive in place, while the center locks the plastic part to the sheet metal. The drive is only held in place from one side.

Finally, several of the cases used snap locks to attach the mostly ornamental front piece. As long as the snap locks are easily accessible, this makes it very easy to remove the front, for example when mounting front fans. The opposite side can be mounted on a hinge mechanism to allow for easier (dis)assembly.

Figure 18: The front piece can be snapped on to the frame.

2.5 Room for improvement

Based on the previous two subsections, I reached some conclusions regarding what opportunities there are for improvement. Many cases have a lot of space set aside for 3.5” hard drives and 5.25” DVD-drives, despite being dated standards. Personally, I believe most cases could remove some functionality, cutting costs, without compromising on the users’ needs. This allows for tighter and cheaper builds while maintaining proper airflow.

I also saw that most cases had the power supply mounted so that it either pulled in warm air from the processor, or straight from the dusty floor (which warrants the use of a dust filter). A solution to this was found in the *Corsair Carbide Air 540 Cube* [15], which places the PSU behind the motherboard tray, and turns it on its side. This means that the PSU pulls fresh air from the outside of the case, and exhausts it towards the back. The drawback is that the computer case now requires a wider design, while cutting the height.

Figure 19: The *Corsair Carbide Air 540 Cube* has a vertically mounted PSU.

3 Design and CAD Methodology

After going through existing computer case alternatives, I decided that a product built from the ground up for modern, enthusiast hardware within a small volume would be the most interesting alternative. Aesthetics are secondary, but as mentioned previously, this is often added on to the basic frame using clips.

If designed well, such a product could please both computer enthusiasts and beginners at the same time. The goal is to find a design compromise which will satisfy the needs of customers looking for a compact, aesthetically pleasing, silent case that can fit enough components for an enthusiast.

3.1 Requirements specification

- Fits the following full sized enthusiast components at once:
  - Maximum GPU length of at least 300 mm
  - Maximum PSU length of at least 200 mm
  - Maximum CPU cooler height of at least 160 mm
  - Fits an ATX-motherboard
  - At least one legacy 5.25” disc drive
  - At least one legacy 3.5” HDD

  - At least two 2.5” SSD/HDDs
- Provides sufficient airflow for a positive pressure setup. The air intake should be filtered.
- Comparable ease of assembly of computer hardware compared to mentioned alternatives, by avoiding a specific mounting order when possible.
- Low external volume, comparable to that of mITX-motherboard based cases, despite fitting a ATX-motherboard:
  - Maximum height of 350 mm
  - Maximum length of 400 mm
  - Maximum width of 300 mm
  - Maximum total volume of 40 L
- Relatively cheap to manufacture with few or no non-standard practices.
- Includes cable management.
- Clean, minimalist aesthetics.
- Has been designed with noise reduction in mind.

3.2 High-level Design

With the listed requirements in mind, I began a high level design phase by downloading models of large computer hardware (listed in the Rendering section). In a *Solid Edge* assembly, I shifted the models relative to one another to get a feeling for how the parts would have to be mounted, and what outer dimensions would be needed. The *Corsair Carbide Air 540 Cube*’s PSU location was chosen as it separated the airflow, and would let the height of the case be governed entirely by the height of the motherboard.

When aligned with the motherboard, I found that there was plenty of space available above the power supply. The thickness of the PSU is enough for both the DVD drive and a 3.5” HDD. 2.5” units are small enough to fit almost anywhere, so the exact layout for them was left until later.

In order to build a silent case, it is best to use as big fans as possible, in order to transport as much air as possible at a minimal rotational speed. This led me to put a 200mm fan in the front of the case. In order to achieve positive pressure within the case, this airflow produced by the front fan needs to be higher than that of any output fans. A 120 or 140 mm fan can be mounted at the back of the case.

The CPU cooler and graphics card height determines the distance of the motherboard tray from the side panel. By choosing an extra low CPU air cooler, or opting for a liquid cooling solution, as well as placing the graphics card on a riser, the design could be made even tighter, but this would severely limit which components work together in the case.

Ultimately, I needed some rough minimum measurements in order to design the main case frame. These measurements are shown in figure 20.

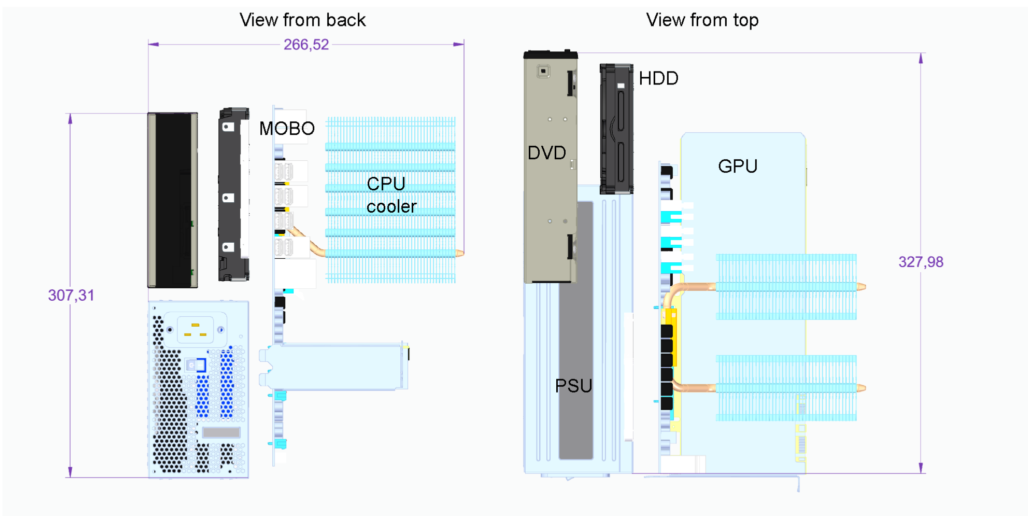


Figure 20: The general layout and the minimal measurements in mm.

3.3 Outer Shell

Based on the cases that were investigated, it seemed possible to design the outer shell of the case in one sheet metal piece, which is then bent into the desired shape.

Since I opted for a large 200mm fan in the front, it was hard to fit the DVD drive there as well. It is often seen as legacy hardware that is very seldom used by most users, so I actually decided to let it face the back of the case. This frees up the front for a very minimalist design, where a mesh dust filter can be attached.

The exterior fan should not need a dust filter, assuming that positive internal pressure can be created by the frontal fan. However, it still needs some kind of grill which should not impede the airflow, lead to unnecessary noise, or be possible to stick one's fingers through. I found a very helpful investigation conducted by Matt Bach [16], which established that a wire based grill was the quietest and least restrictive of the evaluated grill designs, but I found it lacking in design, and it requires an additional part. A mesh did not increase the noise level much, but was restrictive to the airflow. A ”loose swirl” pattern seemed like a good compromise that could be cut from the sheet metal, as shown in figure 21. The fan is kept slightly from the grill itself due to adding indentations by the mounting holes. The holes do not have to be threaded, as the screws are fastened in the fan itself. The indentations also keep the screw heads flush with the back of the case.

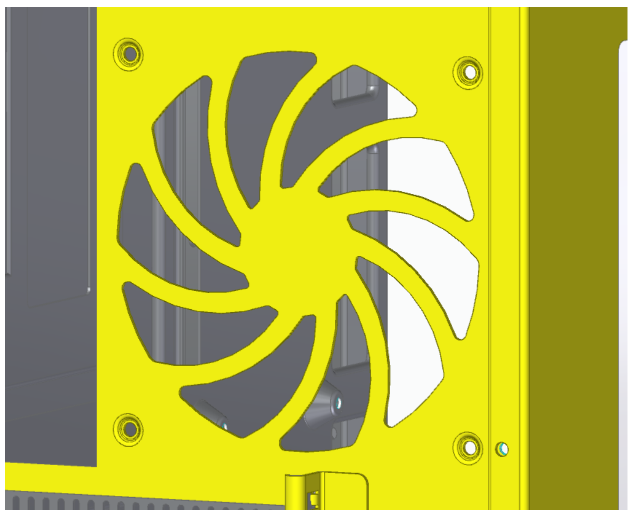


Figure 21: 120 mm fan grill of the ”loose swirl” variety.

The vertically mounted power supply needs to be able to pull in air from the side. Originally, the idea was to stick a similar fan grill on the side panel, but a filter would be better to prevent dust buildup, and the fan placement from the back of the PSU seems to vary between different models. This led to a solution of using glue to fasten a mesh from inside, to achieve the result shown in figure 22. As you can see the PSU is mounted at the back of the case using standard screw placements based on dimensions specified by Intel [18]. The mounting area is slightly indented for sturdiness and fitting the mounting screws beneath the left side panel, allowing for a slightly more compact design. The bottom of the case has an indentation for the power supply to rest on, which could optionally be fitted with a damping pad if any vibrations propagate.

Figure 22: Rectangular opening covered with a mesh dust filter.

The side panels are of a pretty standard design, with an internal rail along the bottom and front for positioning, and a single screw for fastening the panel on the back. Often more than one screw is used, but one of the cases I investigated seemed to do fine with just a single one. Naturally, any design problem requires iterations, so this may be something that would be changed.

The feet of the case are made by simply adding square dimples to the bottom, and adding stamped adhesive rubber feet to the bottom, as seen in figure 23. This solution could also be done without any dimples at all if the feet are thick enough, but perhaps it is cheaper to opt for the ”pop-in” feet found in most cases.

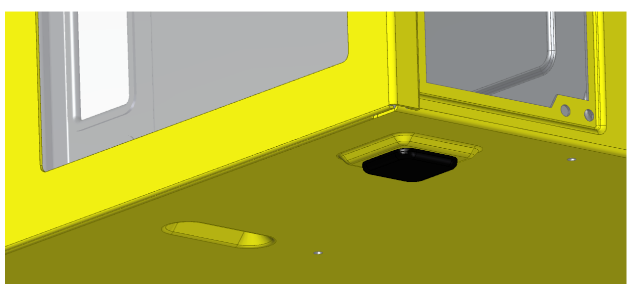


Figure 23: Rubber feet adhesives stuck onto square dimples.

The back of the case features different ports for the DVD drive, I/O-panel (containing USB ports, etc) for the motherboard, and the PCI slots, as shown in figure 24. These all require precise positioning in order to fit everything together, and was quite tricky to get right. Note the small ridges between the PCI-slots and by the DVD-drive slot. This is to provide the thin strands of metal some extra rigidity, and was inspired by several of the investigated cases.

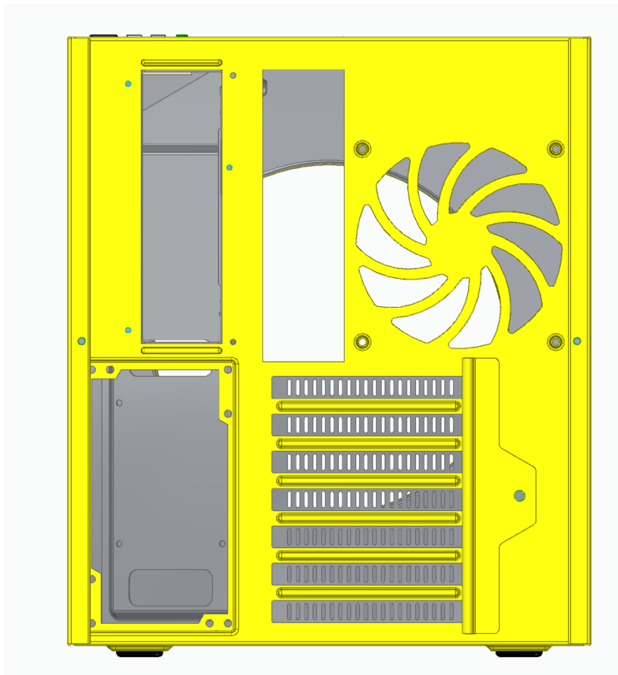


Figure 24: The back of the computer case required precise dimensioning.

An input/output interface for the user was placed on the top of the case. 2 USB 3.0 ports were included, a power button, and 3.5 mm ports. In order to fully appeal to enthusiasts, I also decided to add space for a 240 mm radiator. Here there was no simple way of avoiding external screws, in order to attach the radiator itself. The mesh net is simply placed from above, and screwed in through the threaded holes and into the optional radiator, as seen in figure 25.

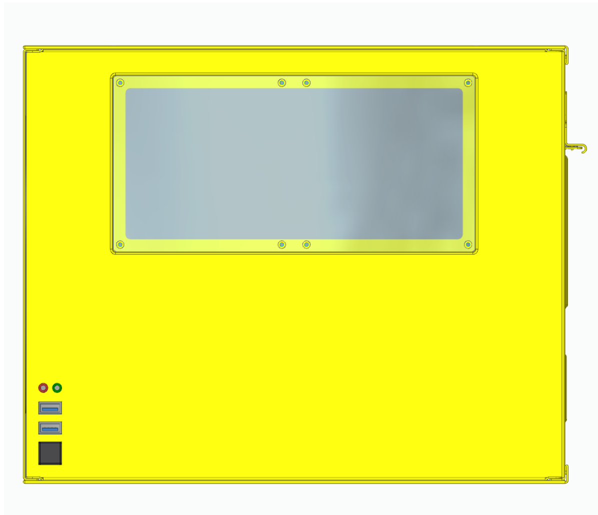


Figure 25: The top includes an I/O-interface and space for a 240mm radiator.

3.4 Motherboard tray

The motherboard tray has to be placed in the middle of the case, and also has to be possible to position when assembling the final product. Like with the front of the case, it is preferable if no screws or rivets are visible from the outside. When looking through the window in the side panel, the visible areas should be as ”clean” as possible. The solution was to let the top simply press against the top, while rivets on the bottom and back of the case hold the motherboard tray steady. By applying a bend to the front of the motherboard tray, where 2.5” storage drives can be placed, the part gets a sturdy base. Optionally, the top flange could have been bent to slightly more than 90 degrees, so as to apply force against the top of the case. This built in tension would stop any vibrations from setting the ”roof” of the case in motion.

Figure 26 shows how the motherboard tray can be inserted into the case frame. Due to the complex motion, this is preferably done by hand. The rivets are also most easily fixed by hand, in case the part slides around inside the case.

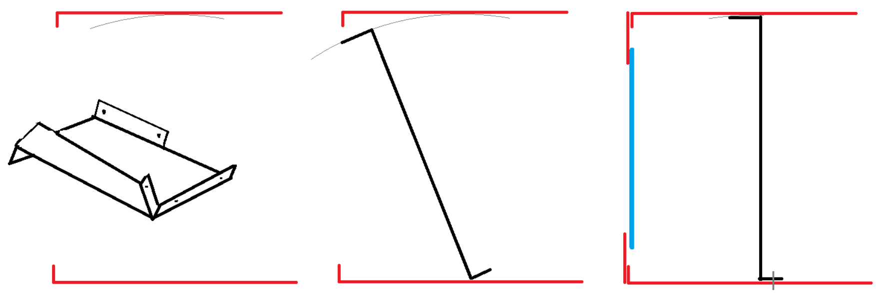


Figure 26: The motherboard tray is first turned to place it inside the case, then rotated into its final position.

The ATX motherboard standard [3] defines the position of the holes, and specifies that the motherboard should be kept at a minimum clearance of 0.25” (6.35 mm) from the motherboard tray. In order to remove the need for separate standoffs, I opted for the use of dimples to raise the board enough, with threaded holes for mounting, as seen in figure 27. The rectangular hole in the corner of the tray is positioned to allow for easy replacement of the CPU cooler, since the cooler fasteners extend through the motherboard itself.

Surrounding the motherboard area, there are open areas for the power supply cables to be attached to the motherboard’s 24- and 8-pin cable inserts. This is also where cables connected to the electronics (power button etc) can connect to the motherboard, or the cables for the graphics card.

Additionally, two 2.5” storage drives can be attached to the angled flange. There is a depression so that the drives slide into place over the screw holes, and sit flush with the flange itself (dimensions from [17]. The angle and position of the drives will redirect the airflow into the main chamber of the case, which is the reason for the slightly odd design choice.

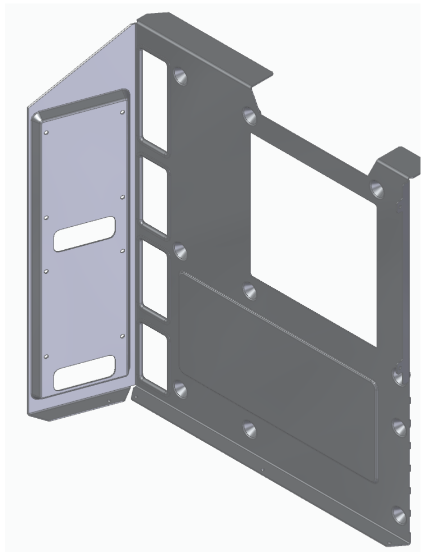


Figure 27: The back of the finished motherboard tray, with all the flanges visible.

3.5 Internal component mounts

The DVD drive and 3.5” hard drive need internal mounts. By mounting a single sheet metal part to the back of the case, the DVD drive can be correctly positioned for the hole made for this purpose (see figure 28). The bay is available only after twisting off the cover, since the bay is only useful for legacy hardware, or possibly fan controllers, neither of which is necessarily present. I have seen a similar solution in a case previously.

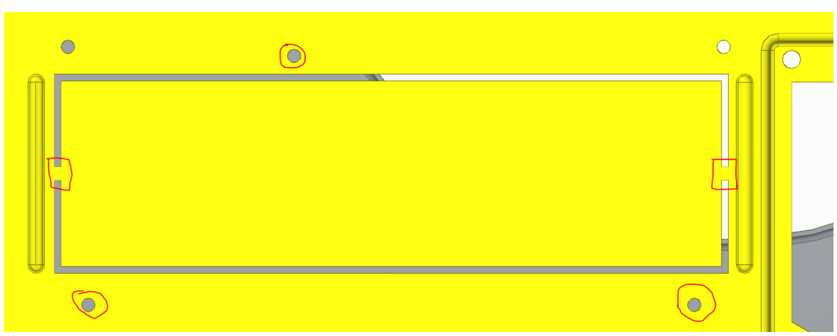


Figure 28: The internal mount is fastened with screws (red circles) and the bay can be exposed by twisting off the cover holders (red rectangles).

The dimensions of the two pieces of hardware are different enough to let the mounts be made from a single piece of sheet metal, by making flanges for attaching the 3.5” HDD on the side of the DVD drive. Although tool less options exist, opting for a standard screws seemed like a much cheaper option, seeing how little work has to be put in to add the hardware. In order to access the screw holes, it is easiest to remove the whole mount from the main case frame first. Note that heat buildup is not a major problem for these specific components, and that they will rarely be used simultaneously.

Figure 29: The mount allows for very compact hardware mounting.

The front fan also needs a mounting system. Due to the goal of having a minimalist exterior, this had to be solved without using any visible screws or rivets to attach this. In order to make the fan easily removable, I opted for magnets. These magnets are mounted to an injection molded filter onto which a dust filter mesh has been glued. Two difference hole dimensions are supported for screwing on the fan. Due to the height of the magnets and indented filter area, the screw heads do not touch the case itself. Note that it may be necessary to remove the front fan while adding any 2.5” drives, which simply requires pulling the part away from the metal frame. The magnets should be able to hold the load, based on a test using similarly sized magnets at home. The four magnets should be kept away from any 2.5” hard drives, but when the fan is mounted, it can not get closer than roughly 30 mm.

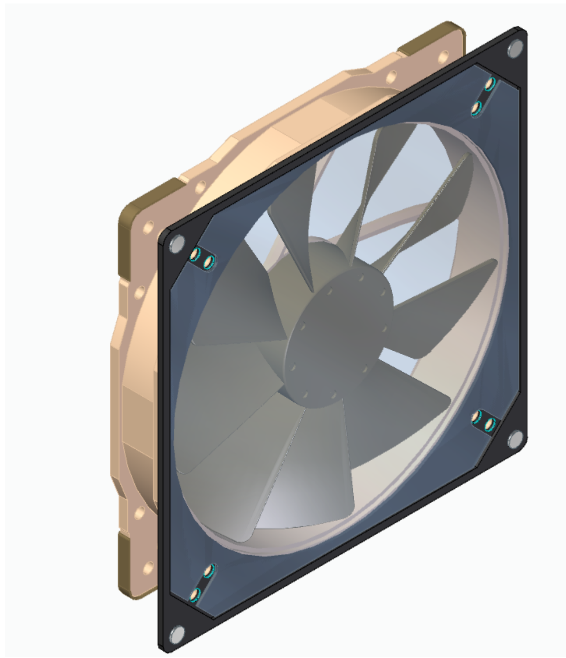


Figure 30: The fan is screwed into a frame and magnetically attached to the case.

3.6 Electronics

The electronics features that are more or less compulsory at the front of the case are USB-ports, a power button, and 3.5mm sound and mic jacks. Optionally, one can also include LEDs for computer activity, FireWire, eSATA, and a reset button. The listed ports seem superfluous as they can be included on add-in PCI-cards. Ideally all parts of the electronics can be mounted as one pre-assembled part, from which cables are attached to the motherboard. To avoid any screws on the top or front of the case, thermal glue or construction tape can be used.

Since designing my own circuit boards is not the purpose of this project, I modeled a simple part with dimensions that should be reasonable for creating an actual electronics component. The result is shown in figure 31. The adhesive would be placed on the black rectangular surface. This means that excessive pushing on the ports would cause some torque to be exercised on the joint, which could pose a problem depending on the choice of adhesive. If this is becomes an issue, a similar surface can be added on the opposite side. Like with all use of adhesives, this should be tested in real life before production begins.

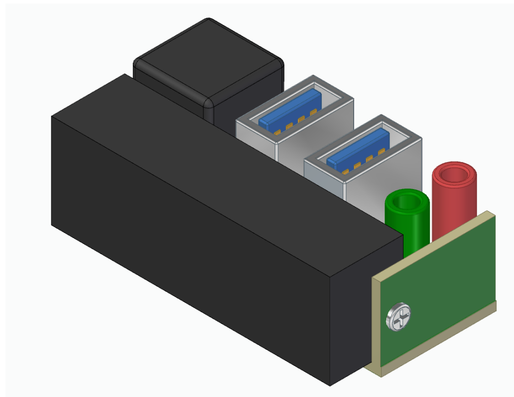


Figure 31: The simplified electronics can fit on one circuit board with separate cables extending from the bottom.

The length of each cable, without attaching the ends to any specific motherboard headers, was calculated to be around 450mm by using the *Solid Edge* Harness environment. About 50-100mm of extra slack is recommended for ease of plugging the cables in and in case the motherboard headers are positioned further away than normal, and can be hidden behind the motherboard tray.

3.7 Manufacturing and factory assembly

When designing the individual parts, I did my best to use as simple and cheap methods as possible. As most of my knowledge regarding manufacturing comes from taking the course MG1016 *Manufacturing Technology*, any assumptions regarding feasible methods and limitations may be incorrect. I limited the number of operations and looked at existing solutions for guidance. Whenever possible I also limited the number of individual parts required, for example by using adhesives, since I had fresh eyes for that topic after recently completing MG2037 *Industrial Bonding*. Note that this manufacturing is not part of the examination of the course for which this project was completed, but some brief thoughts are outlined here.

The outer shell, which is manufactured from a single metal sheet, can be cut using a water jet, laser cutter, or through die stamping. The outer dimensions required are shown in figure 32 below, and should be possible to find suitable machines for. If it is cheaper to split the outer shell into multiple parts, in order to use smaller machines and/or reduce the risk of scrapping the whole part if one operation goes awry, this should be possible. The same operations can be used to manufacture the motherboard tray (figure 33) and the DVD plus HDD mount. A PMI-drawing of the DVD plus HDD mount is available in *Appendix A: PMI drawing of DVD holder*.

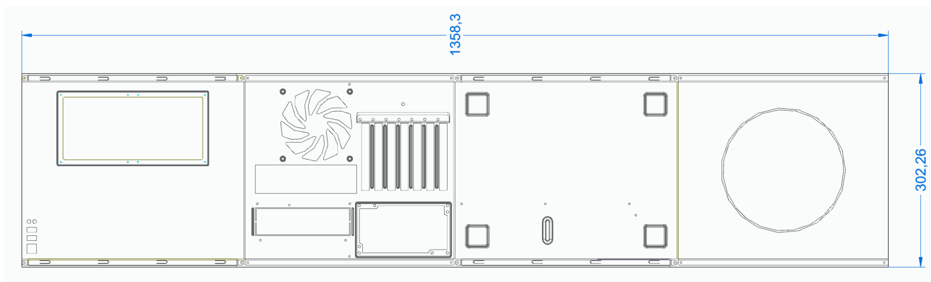


Figure 32: The flattened frame requires a 1400 by 350 mm metal sheet.

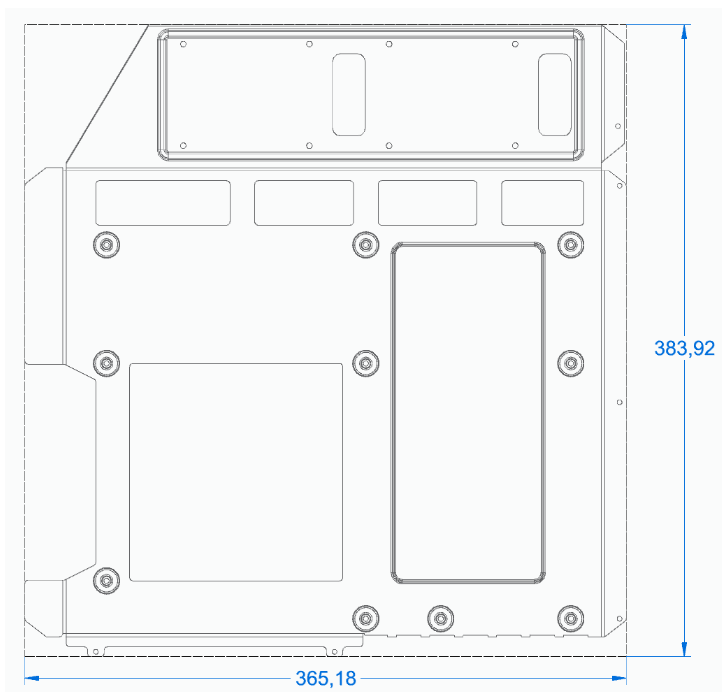


Figure 33: The flattened motherboard tray requires a 450 by 450 mm metal sheet.

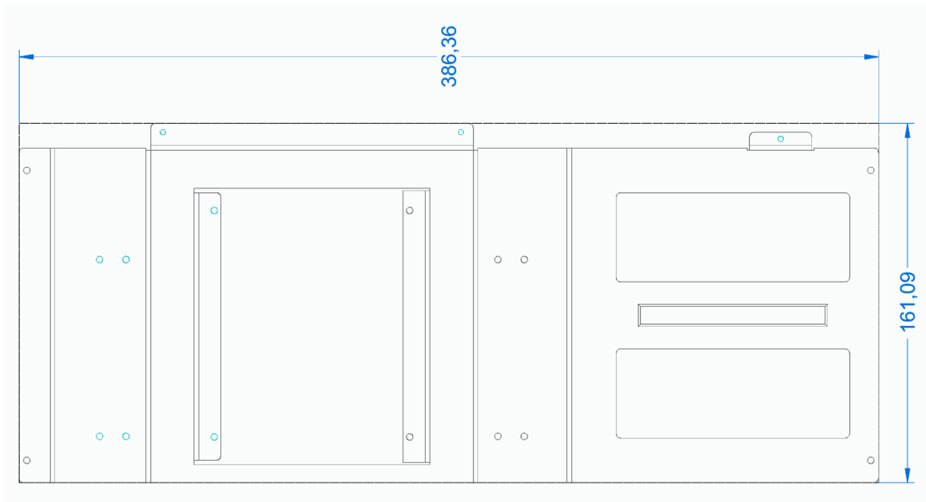


Figure 34: The flattened DVD plus HDD mount requires a 450 by 200 mm metal sheet.

Since there are several large areas that are removed from the main sheet, it is reasonable to cut the smaller parts, like the PCI-slot covers, from this leftover material. Examples of such areas are the front 200mm fan hole and the 240mm radiator hole in the top. This will decrease the amount of material needed, and can hopefully be cut simultaneously as everything else.

Once the flat sheets have been cut out, various indentations and dimples can be created. After that, the outer edges can be bent, before finally bending the sheet into shape, and fixing it using rivets in the corners. As mentioned previously, applying rivets is probably most easily done by hand. There are not that many parts, due to the simple design. The last step is to paint the outside of the case. Multiple layers are required to cover all the corners, and achieve the desired finish.

An animation showing how all the parts in a complete case are to be mounted has been included with the delivered CAD-models. Figure 35 shows the final state of the animation, which was made by using the *caseAssembly.asm* file through ERA >Animation Editor, and then rendering the resulting animation in *Keyshot*.

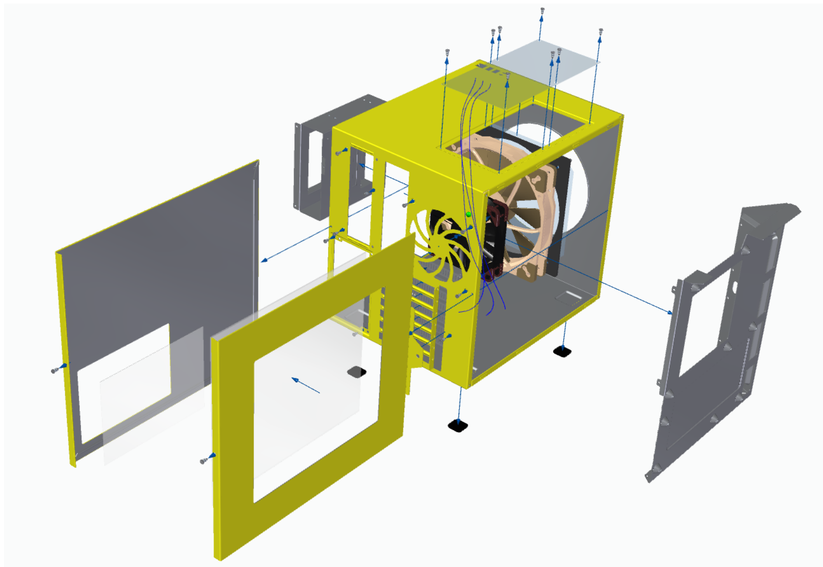


Figure 35: An exploded view of the assembled case.

3.8 End user hardware assembly

One of the requirements set for the result of the computer case was to achieve a ”comparable ease of assembly of computer hardware compared to mentioned alternatives, by avoiding a specific mounting order”. This has mostly been true, but the front fan may have to be removed when adding 2.5” drives, and the DVD plus HDD mount has to be removed before adding any such hardware. However, this feels like a reasonable pay off, considering the overall ”design for assembly” mindset.

The recommended order to follow when mounting hardware within the case is as follows, although most of it is standard procedure, and may not be required for your specific setup:

1. Place the product the right way up.
2. Remove all side panels, the DVD/HDD-mount, PCI-slot cover, and the 200mm fan mount.
3. Place the product on its side, with the motherboard tray facing up. Attach your ESD-wristband to the case!
4. Insert the motherboard I/O-panel. This step is very easy to forget!

5. Mount the motherboard within the case. Screw it in.
6. Add RAM to the motherboard.
7. Attach the processor and cooler including the radiator.
8. Attach the graphic card(s). Once finished, also screw in the PCI-slot cover.
9. Mount the back fan and/or radiator, and plug it into the motherboard.
10. Place the product the right way up again.
11. Mount the 2.5” drives that you will use. Hold the drives on one side of the tray, while fastening them with screws from the opposite side.
12. Screw the 200mm fan onto the fan mount, and place it in position. Plug in the cable to the motherboard.
13. Mount the power supply unit and screw it in.
14. Attach the DVD- and 3.5” drives to the mount, and screw them into the case from the back.
15. Plug in the SATA-cables required for the 3.5”-, 2.5”- and optical drives.
16. Attach any remaining cables from the power supply unit and the case electronics. Make sure to route the cables through the right holes (above the motherboard, by the side of it, or below the 2.5” drives). Any extra power supply cables can be stored behind the 2.5” flange.
17. Celebrate by posting a picture of your build on social media!

3.9 Bill of Materials

Figure 36 is the complete bill of materials (BOM) for the product. Note that the fan assembly consists of two parts which would have to be glued together before sending the product to the end user. This also applies to the Acrylic Window and PSU Mesh parts. It appears as if the cables are not included in the list, but they would be part of the electronics assembly which is in itself made from multiple parts. The material for this part was chosen to silicone to get a reasonable weight. It is also reasonable to package the smaller parts, such as the PCI-brackets and M4-screws in small plastic bags to avoid losing them and easily dispensing the right number of parts. The exact packaging is left as future work.

File Name	Quantity	Material	Mass (Item)
Frame.psm	1	Steel	2,503 kg
PCI_Bracket.psm	7	Steel	0,012 kg
PCI_Bracket_Cover.psm	1	Steel	0,043 kg
MotherboardTray.psm	1	Steel	0,821 kg
DVD_holder.psm	1	Steel	0,324 kg
USB_PWR_AUDIO.par	1	Silicone	0,027 kg
PSU_Mesh.par	1	Aluminum, 1060	0,033 kg
240mmRadiatorMesh.par	1	Aluminum, 1060	0,036 kg
RubberFeet.par	4	Silicone	0,002 kg
FanAssembly.asm	1		0,000 kg
Side_Panel_Left_Window.psm	1	Steel	0,686 kg
AcrylicWindow.par	1	Acrylic, high impact grade	0,171 kg
M4_screw.par	22	Steel	0,001 kg
Rivet.par	16	Steel	0,000 kg
MotherboardHeader.par	3	ABS Plastic, high impact	0,001 kg
Side_Panel_Left_mir.psm	1	Steel	0,942 kg

Figure 36: A list of all the components in the computer case.

4 Downstream Applications and Results

After the model was completed, there are several different downstream applications that can be done in order to use the model for something practical.

4.1 Requirement verification

Before these applications are completed, it is important to verify that all of the requirements have been met. All of the physical dimension requirements are met, as is shown in figure 37. By multiplying the dimensions, the total external volume of 34.7 L is found, which meets the requirements for a maximum volume of 40 L.

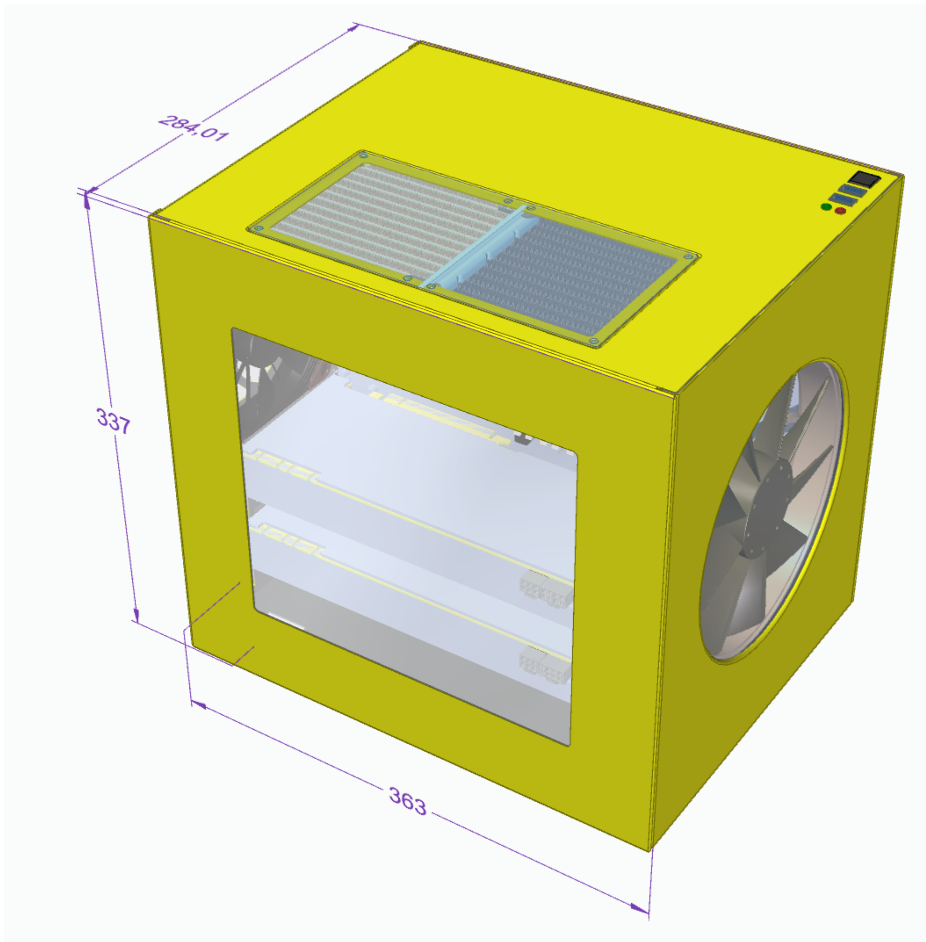


Figure 37: The maximum allowed dimensions are 300x350x400 mm (WxHxL), and a maximum total outer volume of 40 L.

The following assembly (figure 38 shows that the final model can indeed fit all of the required components.

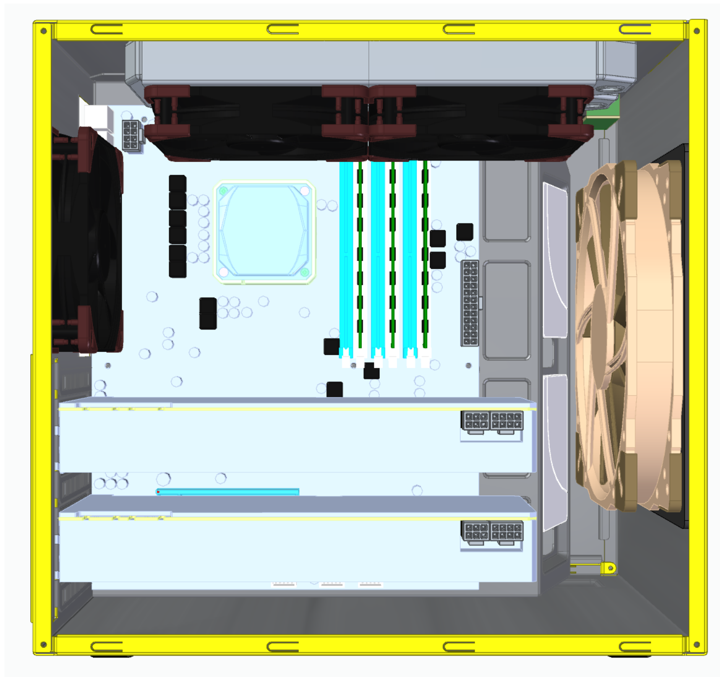


Figure 38: All of the required components fit within the case.

Some of the other requirements are guidelines, rather than precise quantitative data. Air flow and noise levels have to be tested with prototypes, but the design was completed with those requirements in mind.

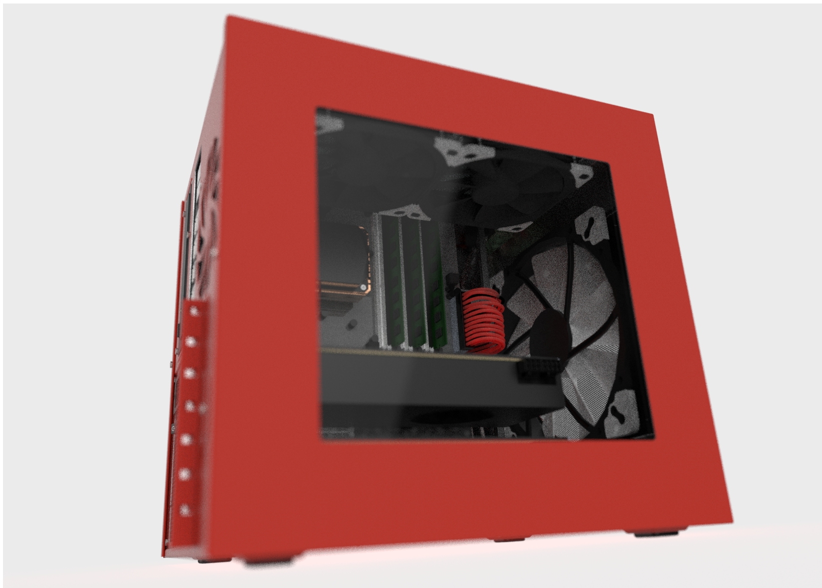
Although not specified by the requirements, it may be helpful to state that the total weight is approximately 6.3 kg. For comparison, the *Bitfenix Prodigy* case [10] has a similar mass.

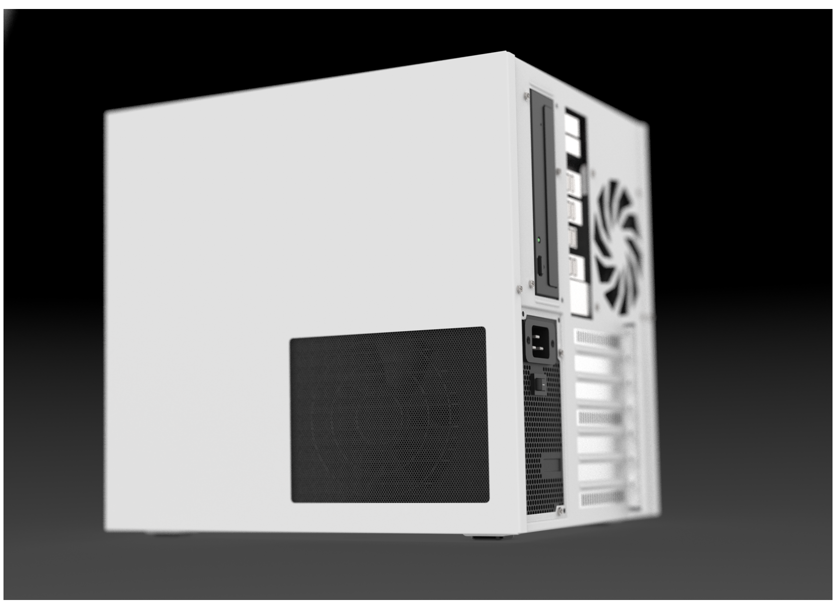
4.2 Rendering

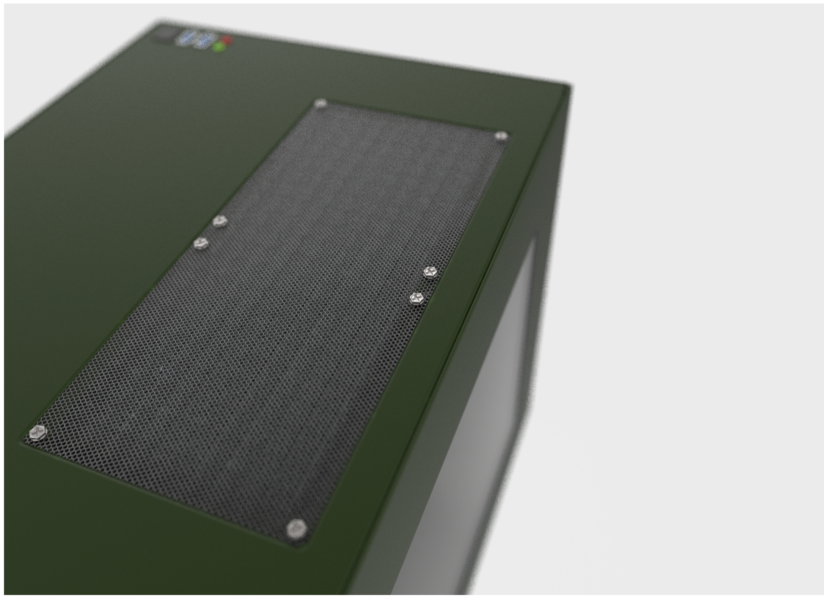
Since this is meant to be a product for consumer use, renders of the design could be very helpful in order to judge whether people would be attracted to the general design. If successful, such renders can also be used for marketing, instead of actually taking the case to a photo studio. Through rendering, it is very simple to change the color of the case, as can be shown in the rendered images below. The images were designed with marketing in mind, either to show off the whole product or showcase a particular aspect of the case. More images are included in the project file folder.

The following *Grabcad* files were used when creating assemblies for renders.

- https://grabcad.com/library/nvidia-geforce-gtx-titan-solidworks-model-1
- https://grabcad.com/library/intel-2-5-ssd-520-series-1
- https://grabcad.com/library/3-5-harddrive-sata-1
- https://grabcad.com/library/noctua-nh-d14-cpu-cooler-1
- https://grabcad.com/library/optical-drive-pioneer-bdr-209ebk-1
- https://grabcad.com/library/corsair-ax1500i-power-supply-unit-psu-80-plus-platinum-fully-modular-1
- https://grabcad.com/library/nf-a20-1
- https://grabcad.com/library/noctua-nf-f12-industrialppc-120mm-fan-1
- https://grabcad.com/library/ddr3-ram-1
- https://grabcad.com/library/alphacool-nexxxos-st30-240mm-2x-120mm-1







4.3 Assembly animation

The case assembly, without any internal computer hardware, has been animated and rendered. The video file is included together with this report.

5 Discussion

The case design lived up to the requirements set up at the start of the project, and the product shows promise when objectively compared to existing cases, but this project is not suitable for manufacturing an actual product yet, as this would require more iterating, physical prototypes, and access to more resources, such as proprietary standards.

5.1 Limitations of model

The design delimitations and the limitations of this model can be listed as follows:

- Model manufacturability has not been strictly verified, but has been compared to existing alternatives and design practices, as guidance.
- No vibration or acoustic analysis has been performed.

- No specific adhesives, paints, or surface preparations have been selected.
- The computer parts themselves have been downloaded from *Grabcad*, and may include inconsistencies. One example is the motherboard itself. The hole dimensions have been verified by the ATX standard [3], but do not quite match up with the motherboard. Whenever possible, I have followed available dimensioning standards.

5.2 Challenges

I believe I would prefer to use a different CAD program for future sheet metal parts and assemblies of this detail, since I ran into multiple problems without apparent solutions. For example, I was unable to create hems on some edges, despite using the same methodology, such as on the holes of the 2.5” cable management holes on the motherboard tray. I was also unable to create tiny beads or louvers in some instances. I have seen this in person on the investigated computer cases, so I doubt this is supposed to keep the user from creating unreasonable shapes.

I also found it very tricky to create the interlocking tabs found in the corners of the case frame, as the program would restrict the actions I could do on the part when the parts initially interlocked. Another problem was bending an ”inner” tab outwards, such as the small cutouts on the sides of the main frame, which are meant to provide some flex against the side panel. Instead removed the material and added a flange manually, which is not very intuitive and quite time consuming.

Another issue was simply selecting faces or edges of both my own and downloaded models when assembling the models, which is the main reason for not including liquid cooling tubes. In some cases, this could be solved by turning off the perspective view mode and disabling the ”reduced steps” option when selecting faces. I am sure that some of these issues are due to user error, but the program has acknowledged issues with intuitive interfaces and bugs.

I tried to include a simple FEM-analysis of a static load acting on the case assembly, but was unable to create a valid mesh of the case assembly, despite trying multiple programs. In the end I decided to omit that part of the project, and leave it as future work.

Too much time was spent on troubleshooting and finding workarounds for this project, rather than producing efficient results, and in the end I decided to cut some corners since most of these problems were not required for the assignment.

5.3 Future work

The qualitative experience of the case is hard to evaluate without also constructing a physical prototype. Some of the requirements were only possible to follow as guidelines, which intentional when setting them up. Aspects that have not been investigated at all, that might provide some value, is how exactly the parts can be manufactured, how vibrations propagate throughout the case, and simulating the airflow within the case. This is beyond the assignment's scope.

Should this design does not live up to user noise expectations, there are several spots where adding a small dampening pad or gasket might help alleviate the problem. Any such spots have been mentioned in the report itself.

No FEM-analysis was completed for the design, due to running into technical problems. Due to the limited forces acting on the product, the results may not even be necessary, but it may help to highlight any areas of the design that could benefit from reinforcement, or that could be made cheaper by removing existing beads or other strengthening features.

A suitable packaging design is required for safe transport, without causing any damage if the package is dropped or shaken (from external objects, or simply loose parts scratching each other), while using a minimal amount of material.

If the case, despite being very small considering the components that can be fit inside, is found to be too big, the design can be made even smaller, although this will limit functionality. One alternative is to fit graphics cards on PCI-E risers, perhaps mounting one on the back of the motherboard, instead of the DVD-drive. If full-size CPU air coolers are not a necessity, that means that a lot of the width can be cut down as well. Requiring a full ATX motherboard to fit within a compact case is of course a contradiction, so by switching over to the mATX motherboard form factor and an SFX power supply, even more space could be saved.

6 Conclusion

The overall project has required a lot of work, but the end results are reasonable. The designed computer case lives up to the requirements set up at the beginning of the project, and can objectively be assumed to be competitive if manufactured, even if the product would need multiple iterations to solve unforeseen problems.

For portfolio use, a webpage about the computer case is available at: `www.johanehrenfors.se/portfolio/Goliath.html`.

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A PMI drawing of DVD holder

The original drawing is available included in the file folder: *PMI_DVD_holder.pdf*.