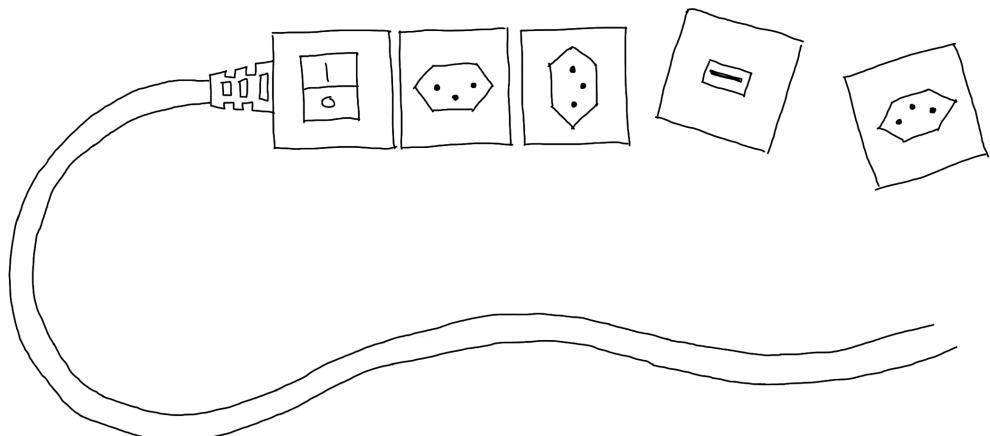


# Modular Power Strip



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# 1 Introduction

Nearly everyone has encountered the following situation: after purchasing a new electronic device, you go home to install it only to find that there is no more room in the power strip to plug it in because of the large and awkwardly-shaped power supplies (transformers) from your other equipment. While we could complain that power adapters should be better designed to avoid this problem, we propose a new, more universal solution – creating a better power strip. We have designed a modular power strip that uses reconfigurable blocks to create a highly-adaptable power solution. Using our product, users can define the size, shape, orientation, and functions of the power strip to fit their needs.

# 2 Product description

## 2.1 Concept

The idea is to have a strip composed of multiple blocks that can be assembled in different ways. The blocks will (in general) have four faces on which it will be possible to connect other blocks. A strip composed of several modular blocks has the advantage of being easily adaptable. It is possible to change the length, shape, and order of the components constituting the strip. Adding or taking blocks away gives the possibility to adapt the strip to personal needs and changing requirements.

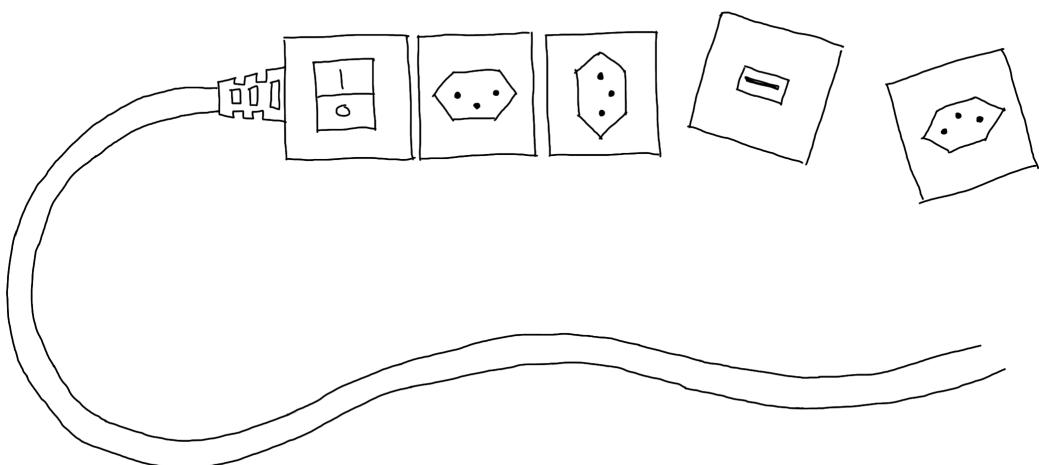


Figure 2.1: Concept sketch

A modular power strip alleviates the problem of bulky power adapters while providing many other benefits. Such a power strip allows some of the following, unique interactions:

- It can easily be expanded with new plugs.
- It can be arranged to eliminate “lost” plugs
- It can be adapted to fit in particular spaces.
- It can include blocks for specialized uses (USB chargers, remote switches, etc.).
- It can have additional switches to turn off a subset of plugs.
- It can be updated based on evolving technological needs.

These are only some of the many features that our product provides. Our design presents a unique, safe, and adaptable solution to the powering of electronics. The idea is to sell

a basic set at the beginning, containing an outlet connection and three blocks for normal plugs. We can then sell additional blocks with different, more-specialized functions.

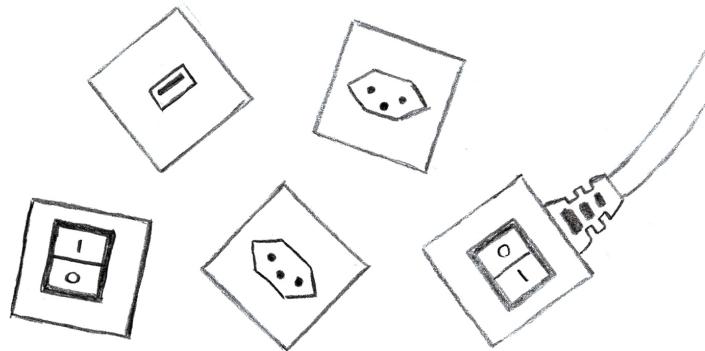


Figure 2.2: Example of blocks

### 2.1.1 Different shapes

Our block-based, modular design allows for the user to adapt the strip to their needs. They can adjust the plug locations and create custom shapes to fit all of their devices and optimally manage the available space. The design also adds an interesting twist to a typically bland consumer product. Figure 2.3 shows an example of the shapes that can be created with our product.

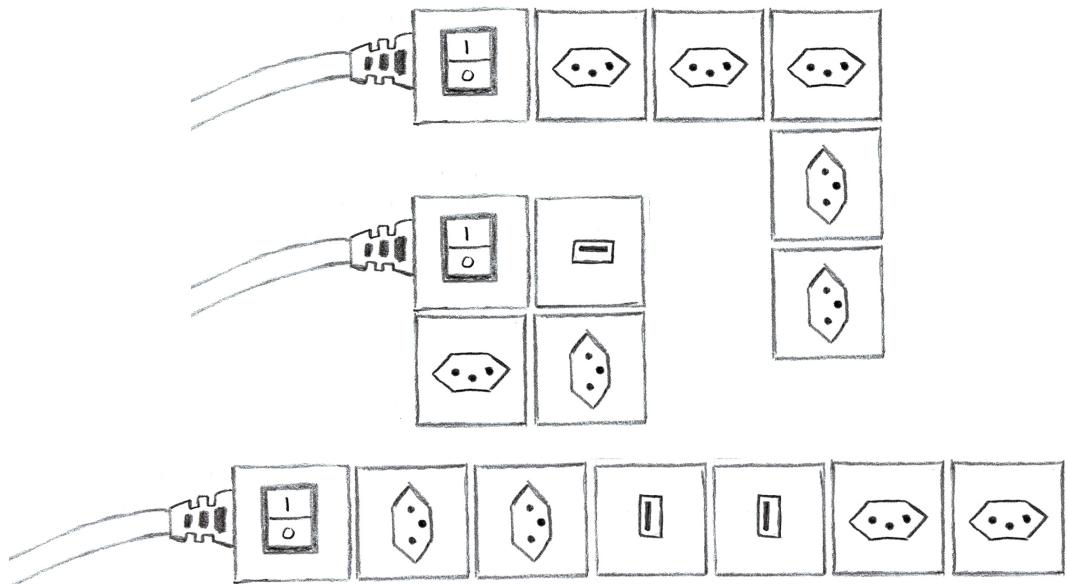


Figure 2.3: Possible configurations

## 2.1.2 Different orientations

In addition to being able to change the configuration of the blocks, one can also change the orientation of a given block. This can help arrange the cables more neatly. With conventional power strips, people often have the problem of blocking strip sites with bulky power adapters. Our product proposes multiple solutions to this problem. One could include a spacer block, or, more interestingly, simply rotate the plug block to make the transformer fit. This ability to rotate blocks is enabled by the common connection interface and square shape.

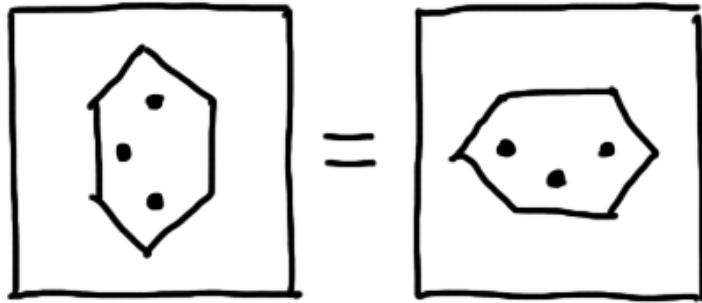


Figure 2.4: Plugs can be used in different orientations

## 2.1.3 Different blocks types

It is clear that a modular system like we propose will need several different kind of blocks which can connect to one another. To begin, we will need a block which connects to an outlet and a series of standard plugs which can connect to it. To give users even more possibilities to personalize their strips, we also propose making a series of other blocks available. Figure 2.5 shows some proposed block types.

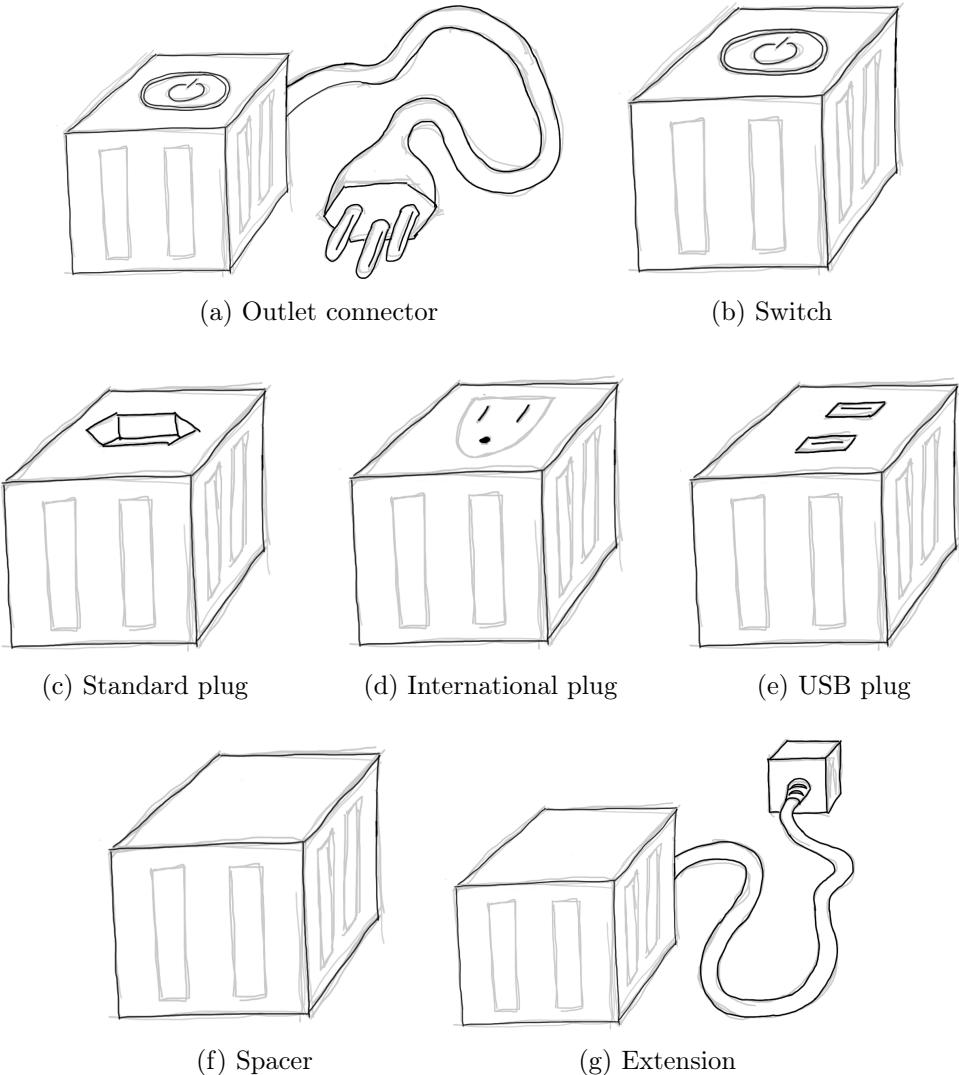


Figure 2.5: Possible block types

In addition to increasing the capacity of the power strip, additional blocks can greatly increase the functionality of the device. For example, including an international plug allows for the connecting of international devices without needing a separate adapter (assuming the device supports the supplied voltage). We can also include specialized plugs like a USB charging block. Given that more and more mobile devices (cell phone, mp3 players, etc.) are charged through USB connections, this may be particularly appealing. Another unique block is a switch (on/off). This gives the ability to power only a portion of the strip (since the blocks are connected in series). As an example, it may be useful to disable only a printer – which is generally used less frequently – without disabling the corresponding computer. Other interesting examples include a remote switch to turn on and off a part of the strip or plugs with special indicator lights. Finally, the system allows for additional blocks to be created and integrated that solve

new user needs as technology evolves.

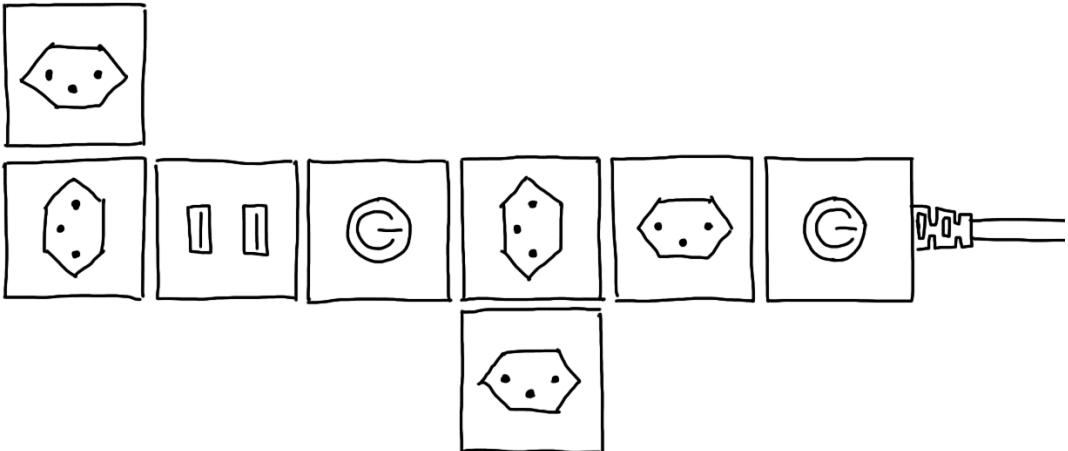


Figure 2.6: Possible configuration

## 2.2 Potential market

We expect our product to be appeal to individuals and families who have a large number of consumer electronics. Since consumer electronics such as mobile phones, mp3 players, printers, and computers all require their own (typically unique) power adapter, users with multiple devices must figure out the often difficult task of how to power all of these devices from a limited number of plugs. As the number of devices people own continues to increase, this problem will only grow. Some examples of groups with an accumulation of electronics who we expect would buy are product include:

- Younger generations with a large number of electronics in their rooms, including sound systems, televisions, DVD players, video game consoles, computers, clock radios, lamps, digital cameras, mp3 players, and/or mobile phones.
- Families whose children have some of the electronic devices mentioned above.
- Families with an accumulation of electronics in their living room, such as Hi-Fi sound systems, stereos, home cinemas, televisions, DVD players, video game consoles, lights, telephone or cell phones, and/or other portable electronics used in the space (laptops, tablets, etc.).
- People working in their office or at home having a desktop with computers, printers, scanners, desk lamps, desk phones, and/or cell phones.

Many of these cases involve placing the product in a public location or living space. Because of this, the aesthetic design of the power strip is also very important. The aim of our final product is to be functional and visually pleasing at the same time. People generally try to hide cables and power strips behind furniture, which is often difficult given the size and bulk of traditional power strips. With an aesthetic and modular power

strip, wiring electronics is made less unsightly, the amount of space used is reduced, and the plugs can be more easily hidden – or simply left visible because they are no longer as unsightly.

## 2.3 Morphological chart

The design of a power strip (especially a modular one) can take many possible forms. In order to investigate some of the possible designs, we made use of a morphological chart. Table 2.1 presents a subset of these possibilities. Our final design uses a logical set of the functional solutions. Furthermore, by selecting different solutions for each function, we can create a variety of other novel products.

Function	Solutions
Power source	<i>Power grid, Generator, Battery, Solar power</i>
Connect to other modules	Magnetic, Screw, Latch, Standard plug, Customized plug, <i>Slide rail, Velcro</i>
Pass power between modules	<i>Electrical contacts, Induction with coils</i>
Connect large power adapters	<i>Rotate plugs, Horizontal spacer, Flexible material,</i>
Turning on/off power	<i>Mechanical switch, Electrical switch, Wirelessly controlled switch, Disconnect blocks</i>
Safety	Temperature sensor, Current meter, <i>Voltage meter, Fuse</i>

Table 2.1: Morphological chart (selected solutions are emphasized)

## 2.4 SWOT Analysis

We believe that our product shows a lot of promise. A company built around such a device could be quite successful. The SWOT analysis presented in Table 2.2 details some of the particular strengths and weaknesses of our idea for a company in a product design and manufacturing field.

	<b>Helpful</b>	<b>Harmful</b>
<b>Internal</b>	<i>Strengths</i> <ul style="list-style-type: none"><li>• Uses existing technologies</li><li>• Product is easy to adapt to new technologies</li><li>• Adjustable form-factor</li></ul>	<i>Weaknesses</i> <ul style="list-style-type: none"><li>• Must find or create a market</li><li>• Large quantity product</li><li>• Similar existing markets</li></ul>
<b>External</b>	<i>Opportunities</i> <ul style="list-style-type: none"><li>• Newness in the market</li><li>• Techno-savvy advertising channels</li><li>• 3rd party custom modules</li><li>• Growing number of electronic devices</li></ul>	<i>Threats</i> <ul style="list-style-type: none"><li>• Safety of the strip</li><li>• Difficult to satisfy multiple standards</li><li>• Limited market size</li></ul>

Table 2.2: SWOT analysis

# 3 Existing products

This section outlines some products that are similar to the concept that we developed. Using this, we can further refine our design and goals.

## 3.1 Conventional power strips

Conventional power strips are the only ones currently available on the European market. They can have different sizes and numbers of plugs but all tend to have a common design. They feature a chorded male plug connected to a line of regularly-spaced, female plugs, often with a single power switch. Figure 3.1 shows a typical power strip from IKEA. In general, power strips fall into two categories: consumer and professional. Consumer strips are designed to be low cost and typically feature 3-6 plugs, while professional power strips are more expensive and tends to have better protection and/or higher capacity. Here are some characteristics of conventional power strips:

- Allows for the connection of multiple devices
- Often feature a single power switch
- *Price:* from 8 CHF for a strip with three outlets to over 100 CHF for safety or high capacity strips; average price 25 CHF for a 6 outlet strip

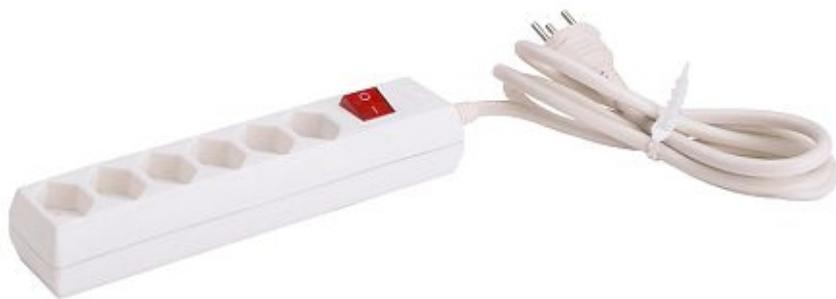


Figure 3.1: Conventional power strip (IKEA KOPPLA)

## 3.2 Pivot-Power

Figure 3.2 shows the Pivot-Power<sup>1</sup>, a commercially available, flexible power strip which allows the user to change the product's shape to fit bulky adapters. Designed by Jake Zien and produced thanks to online supporters, it has the following features:

- Supports up to six connections
- Allows for bulky power adapters without blocking plugs
- Can take many forms (circular, zigzag)
- Switch can be used to disconnect power
- Has a stylish design
- Only available for US power plugs
- *Price:* 30 USD



Figure 3.2: Pivot-Power

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<sup>1</sup><http://www.quirky.com/products/44-Pivot-Power-Flexible-Power-Strip>

### 3.3 PowerSquid

The PowerSquid<sup>2</sup> is seen in Figure 3.3. It is created by Flexity, LLC and is manufactured by Philips Accessories and Computer Peripherals, A Philips Electronics company. It has won several design awards and has the following features:

- Supports up to 6 connections
- Flexible connections allow for bulky plugs to be connected
- Some models feature indicator lights
- Power switch
- Surge protection
- *Price:* from 25 USD for a strip with 5 outlets and low protection to 60 USD for the premium 6 outlet + DSL & cable protection Calamari Edition



Figure 3.3: PowerSquid

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<sup>2</sup><http://www.powersquid.com/>

### 3.4 Plug King

The Plug King<sup>3</sup> (seen in Figure 3.4) was designed by Jeverss Choo and Ng Yi Han at the National University of Singapore, was supposed to be marketed by a student startup, but the venture fell through. Nevertheless, the design proves interesting with the following features:

- Modular power strip where outlets can be added or taken off
- Supports different kinds of connections including USB and international plugs
- Enables novel connections like a wireless door chime
- Refined design



Figure 3.4: Plug King

<sup>3</sup><http://www.copperred.com.sg/about.html>

### 3.5 Multi-Tab

The Multi-Tab power strip<sup>4</sup> (Figure 3.5) was designed by Soon Mo Kang but never reached the prototype stage. Nevertheless, it has the following attractive features:

- Modular design to which one can add and remove outlets
- Stickers used identify what is plugged into each module
- Mechanical levers to unplug individual devices
- Switch to disable to the entire power strip
- Ability to rearrange modules
- Refined design

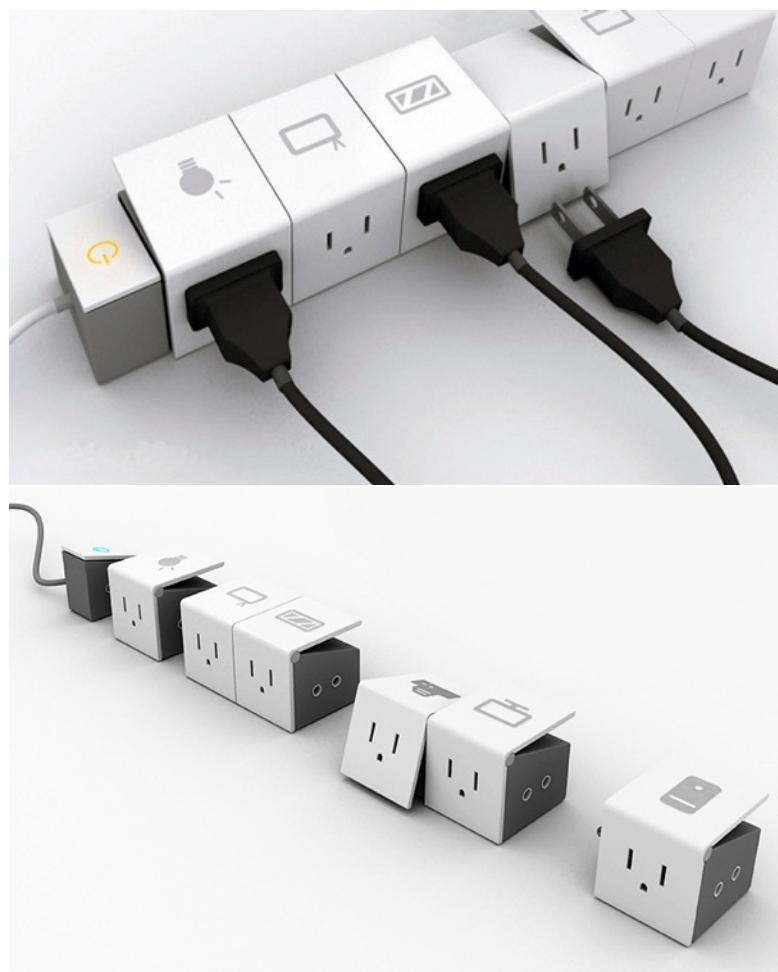


Figure 3.5: Multi-Tab

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<sup>4</sup><http://www.yankodesign.com/2010/02/19/tab-the-power-strip/>

### 3.6 Socket Like Brick

Designer Chih-Yao Chen's created the Socket Like Brick<sup>5</sup> (Figure 3.6), a simplistic, modular power strip. It was never brought to market and has the following characteristics:

- Modular design allows plugs to be added or removed
- Plugs of different length to accommodate different sized adapters
- Each module is standalone and plugs in a standard outlet
- Uses US standard plugs



Figure 3.6: Socket Like Brick

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<sup>5</sup><http://www.yankodesign.com/2011/11/07/too-many-sockets-make-a-brick/>

### 3.7 E-rope

The E-rope<sup>6</sup> is a modular power strip designed by Min Kang, Sung Hun Lim, and Miju Kim. While the design never left the concept phase, it has the following proposed features:

- Modular design allows plugs to be added or removed
- Units can be rotated by 180 degrees to change the direction of the strip
- Rotating of a module by 90 degrees shuts off the power
- Lights to indicate power

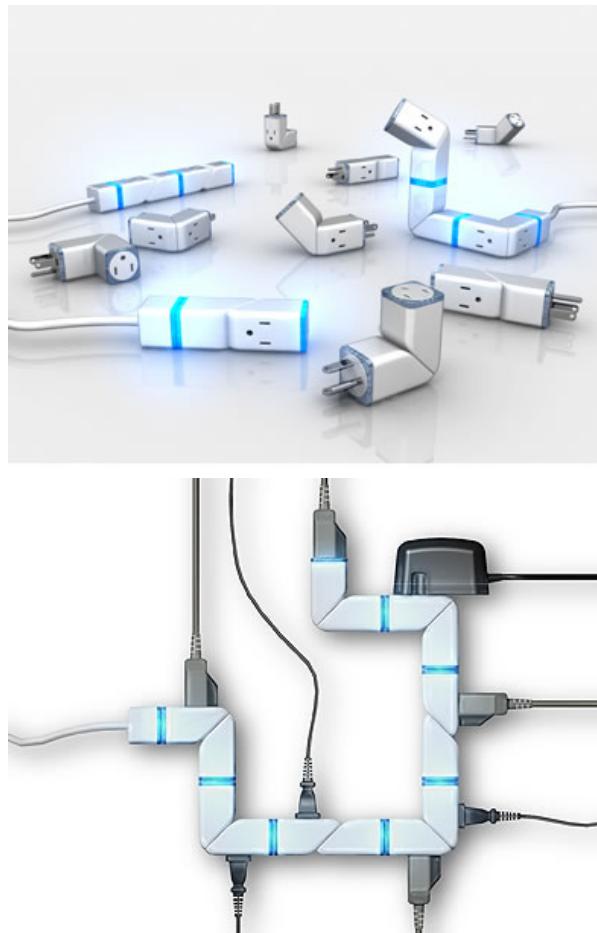


Figure 3.7: E-rope

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<sup>6</sup><http://minkangdesign.com/erope/erope.html>

# 4 Requirements

## 4.1 Requirement overview

Customers expect some basic features from a power strip. In addition to this, our modular power strip has several unique requirements that set it apart (such as an adaptable capacity). Here is a list of the overall product requirements:

### Requirements of conventional power strips

- Deliver power
- Power multiple devices simultaneously
- Support standard plugs

### Additional requirements of our power strip

- Adjustable number of outlets (blocks can be added and removed by hand)
- Supports specialized plugs (e.g. USB plug, international plug)
- Blocks can be connected into different shapes (2-dimensional)
- Blocks can be connected in different orientations (90 degree increments)
- Parts of the power strip can be activated or deactivated separately

### Requirements related to safety

- Ensure inaccessibility to the electrical system
- Surge protection

### Subjective requirements

- Aesthetically appealing
- Intuitive (easy to operate)

## **4.2 Detailed functional requirements**

Table 4.1 lays out the detailed functional requirements of our product. Next to each function we list a criteria and the level that we hope to achieve with our product. We have also prioritized the importance of each function in our final design. A priority of 1 means that the product cannot be presented without this function. A priority of 2 means that it is important to include the function, but the product can still be presented without reaching the desired level. A priority of 3 indicates that it would be a bonus to fully integrate this function.

Function	Criteria	Value	Priority
<i>Power Supply Block</i>			
Connectable to the standard power plug of the country of sale	Connectivity	Type F (CEE 7/4)	1
Supports standard voltage in country of sale	Voltage	230 [V]	1
Connectable to other modules by side	Connectivity		1
Supports total electrical current through strip	Current	15 [A] max	1
Cable length	Length	1 [m]	2
Maximum size of a block	Dimension	60*60*60[mm]	2
Containing a switch	Current	0 [A] when “off”	2
Surge protection	Energy	600 [J]	3
LED indicator light	Interface		3
<i>Additional Modules</i>			
Connects to at least one neighboring block	Connectivity		1
Power drop between modules	Voltage	< 0.1 [V]	1
Standard plug size for country of sale	Connectivity	Type F (CEE 7/4)	1
Able to pass full electrical current of strip	Current	15 [A] max	1
Supports standard voltage in country of sale	Voltage	230 [V]	1
Number of supported connections	Connectivity	4 (one on each side)	2
Switch module which blocks current between connected blocks	Current	0 [A] when “off”	3
USB module which has 2 USB ports for low-voltage DC charging	Connectivity	5 [V], 2 [A]	3
Child-safe connections on standard plugs	Safety	DIN EN 60529	3
International plug supported	Connectivity	US / UK plugs	3

Table 4.1: Functional requirements

# 5 Detailed design

## 5.1 Functional decomposition

Our system can be broken down into several subsystems. Each of these imposes constraints on the others, and they all must be brought together to create our final product. We have purposely tried to limit the number of components in our design in order to simplify assembly, ensure reliability, and keep costs down.

### Mechanical

- Case
  - Plugs
  - Switches
- Module connections

### Electrical

- Outlet connection
- Power distribution
- Electronics
  - Indication (LED)
  - USB (DC power adapter)

## 5.2 Case design

The case of each module holds all of the components together and facilitates interfacing with other modules. We decided early on to limit the inter-module connections to 4 faces (90 degrees), logically making a block or cube shape. This allowed us to simplify the design while still retaining a large variety of possible configurations. This decision also simplified the electrical connections between modules (discussed in 5.5).

There are two primary components to the case: the body and the faceplate. Figure 5.1 shows an example of these components. The body is hollow and open on the top. The four outer surfaces have a special slide interface to connect with other modules.

There are also slots on the inside to hold the power distribution system and a special clip interface to attach the faceplate. The faceplate has 4 integrated clips to secure it to the body – one clip per side. The decision to clip on this component minimizes the number of parts and facilitates assembly. The internals of the body and faceplate are dependent on the particular module. For example, a switch or USB block contains additional electronics and a unique top.

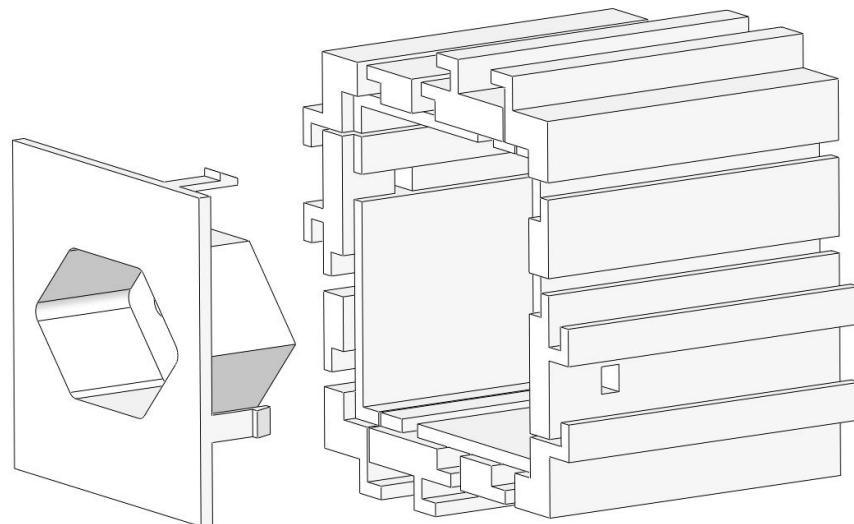


Figure 5.1: Case components

The casing will be manufactured in house out of injection molded polypropylene. Polypropylene has adequate mechanical properties, a low cost (2.5 CHF / kg), and is widely used for this sort of production. Creation of the mold would likely have to be outsourced.

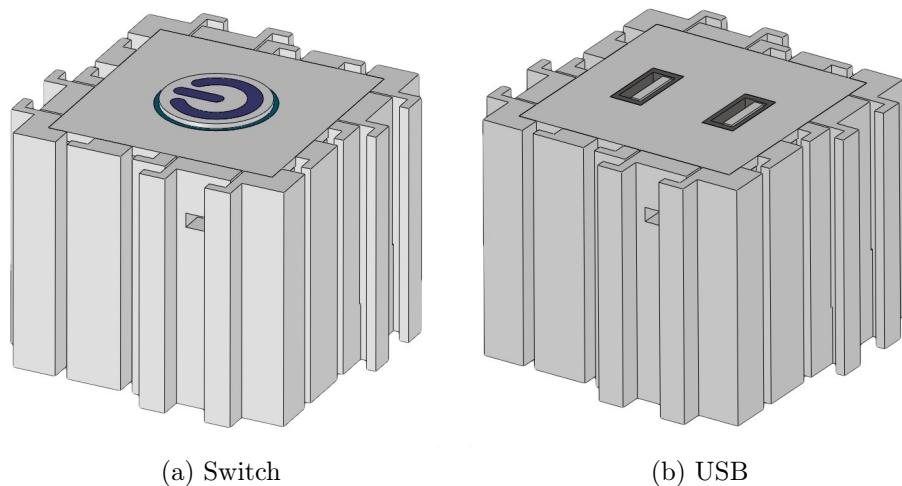


Figure 5.2: Assembled casing for different blocks

## 5.3 Module connections

In order to have a common, secure, and easily adjustable interface between modules, we use a custom slide rail on the sides of each module. Each face has four slides, two that stick out and two that go into the face. Within these slides are the connections for the power distribution. Because the interface is common to all of the different blocks, module types can be easily swapped out and arranged in whatever configuration the user prefers.

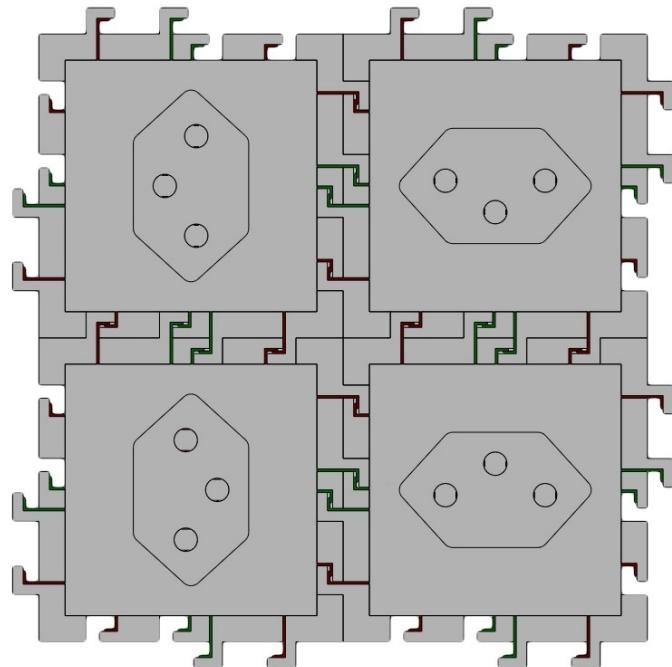


Figure 5.3: Example of connection between modules

Sliding the blocks together is easy yet very secure. The modules remain locked to one another in two dimensions. The design of the slide mechanism also covers the electrical connections, leading to a safer product.

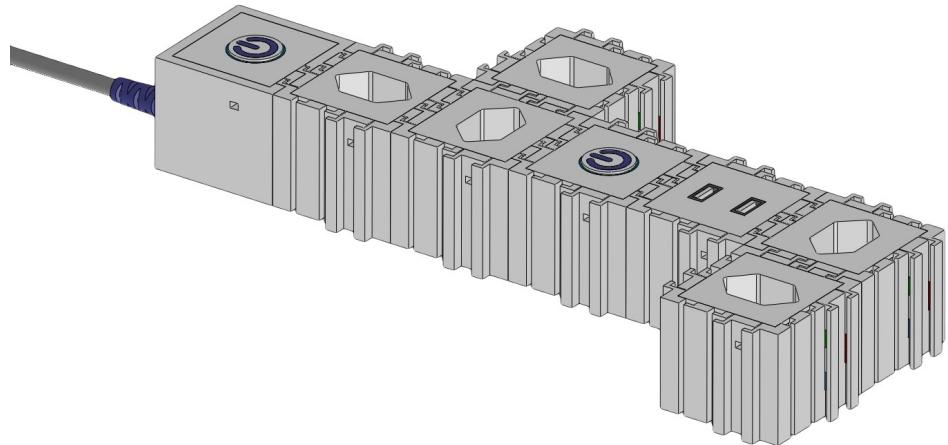


Figure 5.4: Possible configuration of power strip

## 5.4 Outlet connection

A key component of the electrical system is the outlet connector module. This connects the power strip to the grid, provides a on/off switch, and handles the surge protection. The design of this module is similar to the other blocks except that it has more complicated internals, and it has a power cord coming out of the body. The over-current cutoff and surge protection circuitry is contained on a specialized circuit board within the case. The faceplate is the same as a standalone switch module, simplifying manufacturing.

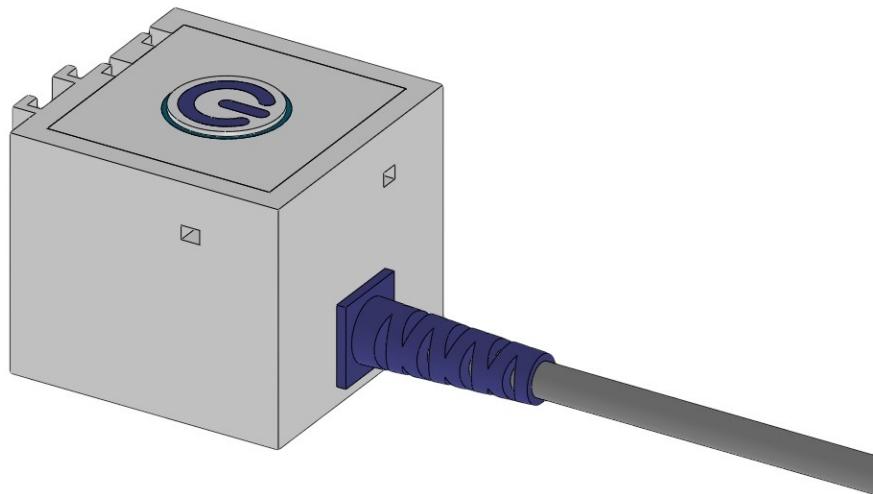


Figure 5.5: Outlet connection block

## 5.5 Power distribution

A power strip must be able to reliably and safely distribute power to each of the plugs connected to it. We have designed our blocks so that the internals are cheap, safe, and effective. All of the contacts are made out of sheet metal. There are three parts: hot, neutral, and ground (Figure 5.6). Each is separated from the others using insulating spacers. These components also provide contacts within the sliding mechanism to electrically connect to neighboring blocks. Figure 5.7 shows how the components are arranged. The insulating spacers are shown in black. The hot connections are placed in two of the four slide locations, while the neutral and ground connections are in the other two at different vertical locations. The prongs from connected devices are placed in the holes causing them to touch the curved contacts. Due to the size of these metal components, each block can pass a significant amount of current. Figure 5.8 shows how the power distribution sub-assembly fits within the case. The components are able to slide in along guides and are held down with the top cover. The contacts are designed so that the electrical connections are automatically aligned correctly. Figure 5.9 shows how the contacts are exposed in the fully assembled module. In general, the electrified contacts are well protected from users. They should be no more dangerous than a normal wall plug.

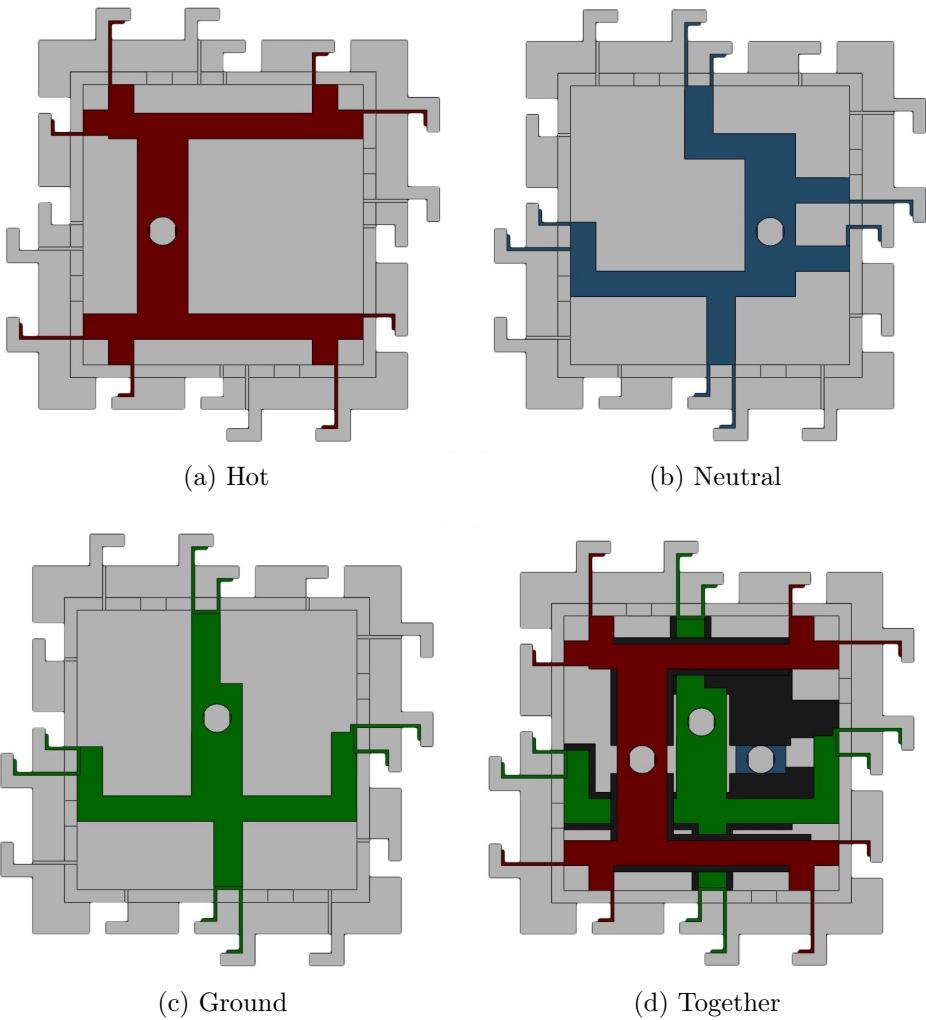


Figure 5.6: Power distribution components

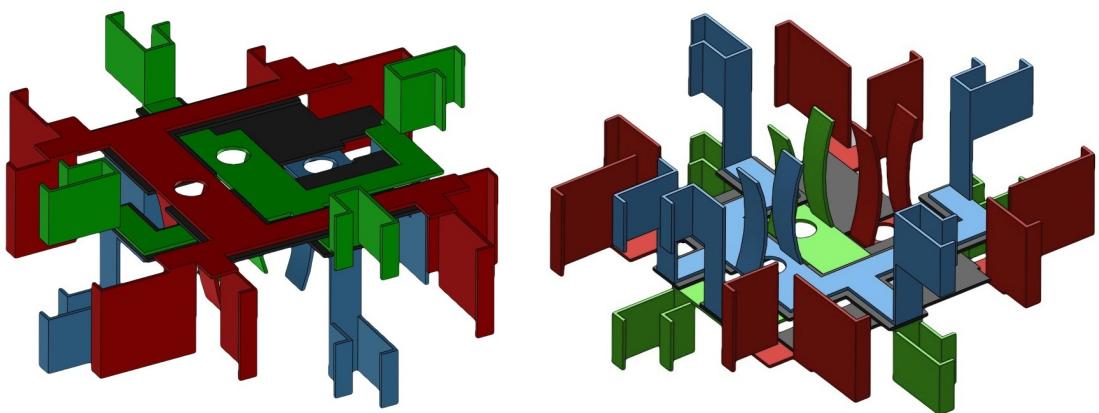


Figure 5.7: Power distribution sub-assembly

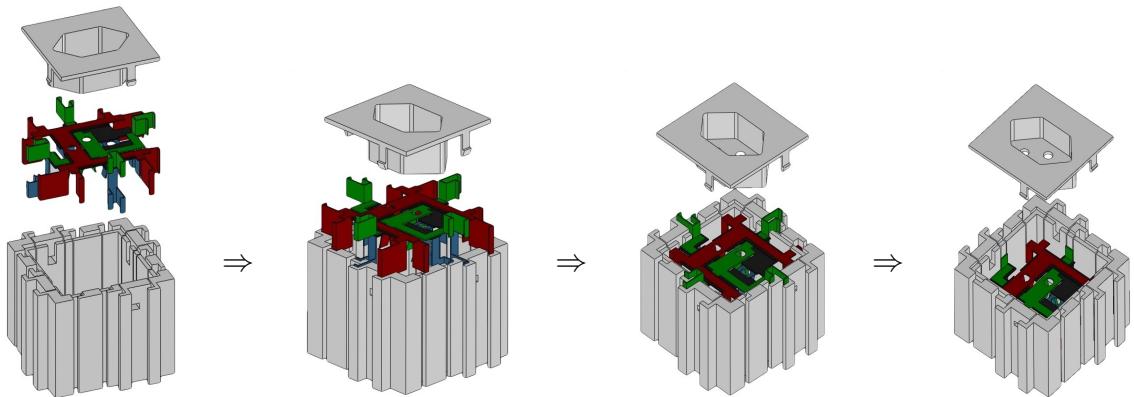


Figure 5.8: Placing the power distribution system in the case

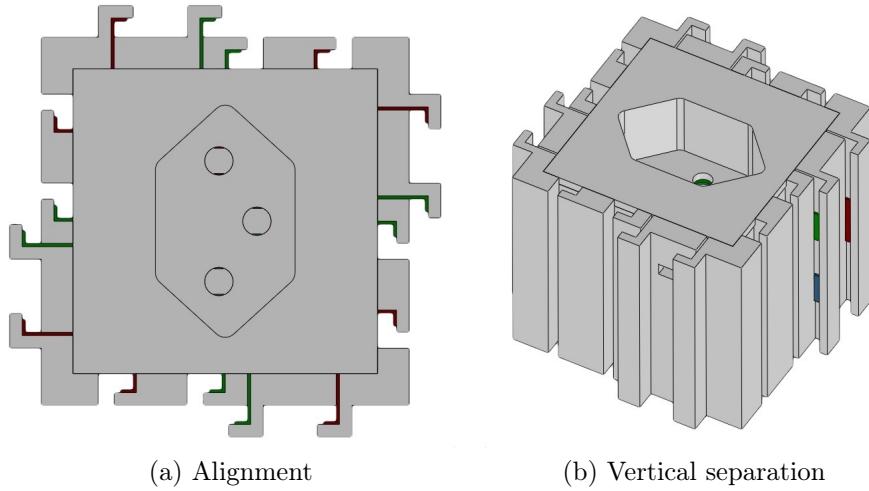


Figure 5.9: Electrical contact points on module

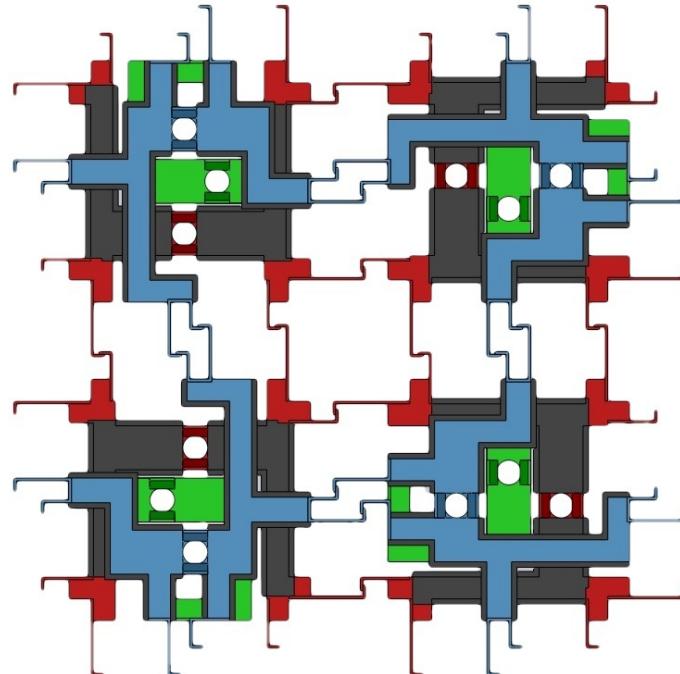


Figure 5.10: Interconnected modules

These components will be manufactured using traditional sheet metal techniques. The parts will be stamped out of larger sheets and bent appropriately. This requires a large upfront investment in equipment, but manufacturing them should be very cheap afterward.

## 5.6 Electronics

Another component of our product is the detailed electrical design. In particular, the current monitoring, surge protection, switches, and USB power converter all need to be designed and manufactured. This design and manufacturing step will be outsourced to specialists in the field. The designs will also be verified to meet all of our safety, power, and size requirements.

## 5.7 Cost estimate

We briefly considered the costs associated with manufacturing our product. After an initial setup cost, it should be rather easy and cheap to develop our product on a large scale.

Part	Outlet	Plug	USB	Switch
Plastic case	1.50	1.50	2.00	1.50
Power distribution	0.50	0.50	0.50	0.50
Insulating spacers	0.20	0.20	0.20	0.20
Cable	1.50	-	-	-
Mechanical switch	0.50	-	-	0.50
USB power adapter	-	-	2.00	-
Assembly	0.75	0.75	0.75	0.75
Testing	0.25	0.25	0.25	0.25
Total	5.20	3.20	5.70	3.70

Table 5.1: Cost estimate (in CHF)

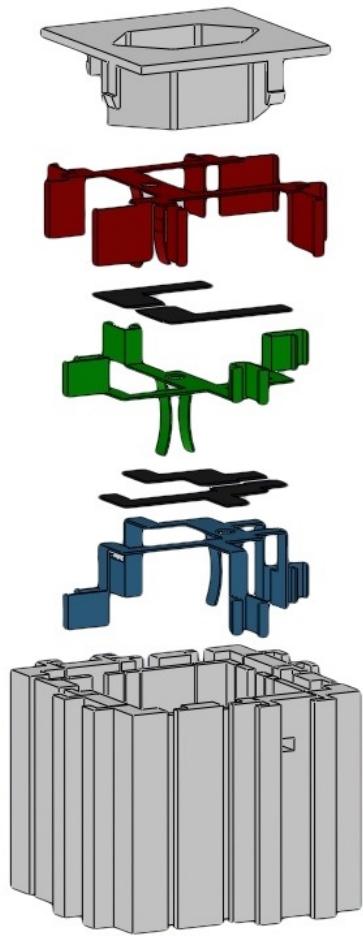


Figure 5.11: Exploded view of a plug assembly

There is to our knowledge no modular power strip system available in Europe, which is precisely our target market. This guarantees the exclusivity and "newness" of our product. Prices must be comparable to the prices of conventional power strips, as customers will probably not be willing to pay much more than for a classic strip. However, the fact that the strip is flexible and aesthetic gives it an added value that can be translated to an increased selling price. We believe that the strip may be sold as a basic set accompanied by three basic blocks, for a price around 50 CHF. During further development, we will have the opportunity to sell our blocks in different colors, making them even more exclusive.

## **5.8 Technology to be mastered**

As the product contains only well mastered technologies, technological innovation is not meant to be a highlight of this product. We are instead interested in the concept, design, and assembly of a modular power strip. On a high level, additional electrical engineering work will be needed to design a secure surge protection system as well as develop the transformer and DC converter for the USB plugs. In addition, more work will need to be done to ensure that our design meets the safety standards in the different countries of sale.

# 6 Conclusion

As the number of electronics in the home grows, there is a pressing need for a smarter power distribution system. We believe that our design for a modular power strip presents an appealing solution to this problem. It allows the user to define the size, shape, orientation, and functions of the power strip based on their particular needs. Our product is useful, adaptable, and shows a lot of potential.

## Closing remarks

We feel that this project fit in well with the goals of the course. Through the lectures we learned about CAD systems while the project let us experience the larger product development process.