Article title

ZigaRetter - The gamified cigarette bin to raise awareness and form actions on cigarette butt littering

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Abstract

Cigarette butt littering is very common. About two thirds of consumed cigarettes end up in the environment. Cigarette butts contain many hazardous or toxic substances that can harm humans, animals underwater or on land and plants. The ZigaRetter is a micro-controller based, gamified cigarette bin attachment, designed to tackle the lack of awareness about the negative consequences caused by cigarette butt littering. Three stages of interaction are used to do so. First, the ZigaRetter attracts people with gamification elements. Second, the device provides users with facts about cigarette butt littering to raise awareness. Third, an alternative is shown by using pocket ashtrays to fight against the improper discarding of cigarette butts in the long term, regardless of location. The ZigaRetter targets young adults frequenting a bar where the device should be installed. The project is open-source and all required information for rebuilding and for further development are available in this article or the source file repository linked.

Keywords

Cigarette Butts, Littering, Sustainability, Gamification, Awareness, Environment, IoT, Dashboard

Specifications table

Hardware name	ZigaRetter
Subject area	• Environmental sciences • Behavioral sciences
Hardware type	• Microcontroller • Field measurements and sensors
Closest commercial analog	Gamified cigarette bins
Open-source license	GNU General Public License (GPL) v3.0 (https://www.gnu.org/licenses/)
Cost of hardware	approx. 135,00 €
Source file repository	https://github.com/ZigaRetter/ZigaRetter

1. Hardware in context

Smoking hampers the implementation of about 10 of 17 Sustainable Development Goals defined by the United Nations in 2015 (United Nations, 2015). During the entire value chain of cigarette products there are sustainability problems on social, ecological, and economic level. Disposal of cigarettes alone has an impact on the SDGs “Clean Water and Sanitation”, “Responsible Consumption and Production”, “Life Below Water”, and “Life on Land” (dkfz., 2017).

Worldwide, around 6 trillion cigarettes are produced and consumed per year by around 1 billion people (Drope et al., 2018). In 2017, about 170,000 of the citizens of Cologne (15 years and older) were regular smokers (Information und Technik Nordrhein-Westfahlen, 2018). With an average consumption rate of 12 cigarettes per day, that is over 2 million consumed cigarettes per day by citizens of Cologne (Statistisches Bundesamt, 2021; WHO, 2015). About two-thirds of cigarettes consumed are not disposed of properly, ending up as litter. Most cigarette butts are thrown on the ground instead of disposed in specific cigarette bins (Kolenda, Knotz, & Eichborn, 2019). So, it is estimated that in Cologne more than 1.3 million cigarette butts per day end up in the streets, close to or inside the Rhine River, in parks or elsewhere in the environment.

Improperly disposed cigarette butts can harm the environment and animals living in it. Cigarette butts can contain up to 5300 substances, many of them toxic or carcinogenic. Most of these substances get into the filter in the process of smoking or at least partly rest in the cigarette butt (Krebsforschungszentrum, 2010). When getting into the environment, these substances have negative effects on the growth of plants (Irrgang, 2020) and are able to harm or kill animals underwater or on land (Kolenda et al., 2019; Novotny, Lum, Smith, Wang, & Barnes, 2009; Primpke et al., 2017). Even children can be harmed through the ingestion of cigarette butts (Novotny et al., 2011).

Many people are not aware of the consequences an improperly disposed cigarette butt can have (Smith, Lawson, Khangura, & Johnson, 2015). The organization “TobaCycle n.e.V.” started to tackle the lack of awareness and the littering of cigarettes by implementing a cigarette butt collecting system. Smokers and businesspeople can join the network. All cigarette butts disposed of in large ashtrays or buckets are collected, taken to the organization and recycled into new pocket ashtrays or collection buckets. In their research, members of TobaCycle found out that the best way to stop littering of cigarette butts is when every smoker would have a pocket ashtray (TobaCycle, 2020).

This context led to three main questions for developing the solution:

1. How to get people in particular locations to dispose of their cigarette butts properly in the short term?
2. How to raise awareness on the negative consequences of cigarette butt littering to form smokers’ actions for the future?
3. How can we nudge people to get a pocket ashtray to prevent littering in the long term, even in the absence of any trash bin or (public) ashtray?

To tackle these questions, we developed the ZigaRetter, an Arduino-based attachment for cigarette bins. It is designed to be installed in front of bars or clubs to attract, educate and nudge young adults. To reach the goals, three stages of interaction are developed:

1. The ZigaRetter has gamification elements, using sound and visualization, to get people attracted to the solution and to let them insert their smoked cigarette butts into the device. The target audience are young adults, so the sounds are chosen to be entertaining for this age group, like famous meme sounds. There are various gamification elements in place, so different types of users get attracted and emotionally attached to the ZigaRetter.
2. To raise awareness, the device shows facts of the negative consequences of cigarette butt littering, so smokers are confronted with the potential outcome of their actions and change their behavior. The list of facts contains some general and some more relatable facts to address rational and emotional thinkers (see Appendix A1).
3. The ZigaRetter provides users information about pocket ashtrays and where to get them to be able to stop littering everywhere you go. In this stage, a cooperation with TobaCycle was enforced. The device should link to the website of the organization, so that smokers and other interested people learn about their work and will buy pocket ashtrays from them.

2. Design Method

To come up with a proper design for the solution, several steps were made. In the first step, we validated the base idea by doing research on the topic of cigarette butt littering and the consequences. Beside finding many negative effects of cigarette butt littering that supported our idea and could be reused in the second stage of interaction, we found some solutions already existing, like the collecting and recycling system of TobaCycle. In repeated interviews with the chairman of Tobacycle, Mario Merella, and with fellow students many requirements were collected on how to develop the existing solutions further. The product portfolio of TobaCycle did not contain any digital products yet. Because digital game-based learning is found to be powerful (van Eck, 2006), and because there are possibilities of adjusting the program based on the needs of smokers, bartenders and other stakeholders, the ZigaRetter should be digital. From then on, we focused on building an attachment for existing cigarette bins in a bar environment. We also talked with a bartender who could give us insights on the perspective of bars. To come up with a suitable case that meets all the requirements, several design iterations were made. The resulting steel case and its design decisions are further described in chapter 3. For designing the software and the outputs, we dealt with the Octalysis framework by Chou (Chou, 2012).

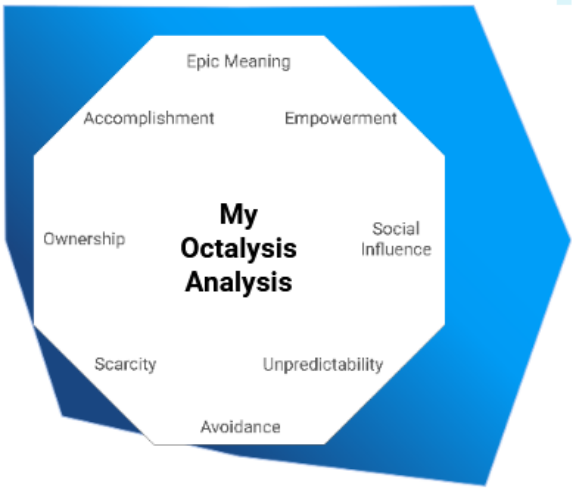

Figure 2-1: Octalysis Analysis

The resulting solution is balanced between the eight core drives with a focus on intrinsic motivation. Research shows that intrinsic motivation leads to a more sustainable influence and deeper learning (Vansteenkiste, Lens, & Deci, 2006). To reach all of the goals and to meet all the requirements for the user interaction, we developed the three stages (see Chapter 1). A first one for engagement, a second one for building awareness and a third one to form actions or give advice. This whole design process led to the solution which will be presented in chapter 3.

3. Solution description

Within this chapter we describe the hardware and software aspects of our solution.

The technical hardware device is an Arduino MEGA2560 connected with several components for input and output and a WiFi module for connecting the device with the Arduino-IoT-Cloud. An USB-B to USB-A cable is integrated to easily access and change the code on the Arduino. A cable for power supply is also integrated and directly attached to the Arduino. The parts are completely placed in a stainless-steel case. The code used on the Arduino and the WiFi module are programs written in an Arduino-specific language which is based on C and C++. It is programmed to provide outputs when a cigarette butt is inserted and to share data with the cloud service. The code is available on the GitHub repository.

3.1 Case

The casing for the solution is designed to fit on existing cigarette bins (especially the CITYC by TobaCycle) but could be built differently to fit on other cigarette bins. As material we used stainless steel, so the device is safe for vandalism from the outside and fire from the inside. The space for the technical parts is separated from the cigarette bin, so the components are not exposed to a potential fire or smoke inside of the bin, caused by glowing cigarette butts. Between the upper and the lower part, there are two small holes to just fit a cable each. They are used to connect the photoelectric barrier with the Arduino. To make the display visible, a cutout the size of the used display is attached to the front. An acrylic glass is sealed in front of the display to protect it from glowing cigarettes, rain and other fluids, like spilled drinks. In the lower part of our device, there is an insertion hole big enough for cigarette butts, but small enough that not many other trash is fitting through. Behind this hole, a metal sheet is installed that has to be pushed away to throw the cigarette in. Therewith the risk that the cigarette butt is not put out before inserting is minimized. To make the maintenance of the technical components easier, the back of the device is retractable. To limit the access without a tool, the back cover is screwed. The power supply cable leads through a hole in the back cover. So, the ZigaRetter can be provided with power when the device is closed.

Figure 3-1: Case on top of the CITYC

3.2 Technical hardware

The technical hardware contains an Arduino MEGA2560, two outputs, one input and one WiFi component. The Arduino MEGA is used because it has a greater number of pins than an Arduino UNO. So, every component can be directly attached to the Arduino while the display does not need a cable connection. In the following, each of the attached components will be briefly described.

3.2.1 Output components

The device works with an audio-visual output to reach users in various senses for a greater influence.
For the visualization of content, a 3.5'' TFT LCD display is used. With a resolution of 480x320 pixels it has a high-quality image and a wide viewing angle. Thus, users of all sizes can see and read the outputs. The display does not have a touch panel because this functionality is not used in this context. It can be placed directly on the Arduino, so no soldering is needed for this component.

Figure 3-2: 3.5" TFT-LCD Display (source: https://www.amazon.de/Anzeigemodul-TFT-LCD-Display-Modul-480x320-Arduino-Vorstand/dp/B07Y5Z6VZB)

To play an audible sound, a DF player module with two Speakers is seriell controlled. The DF player module has a slot where a SD card with audio files can be stored. So, a great variety of sounds can be loaded and used. The component is able to hard code the file format MP3. The 8 ohms 2 W speakers can be soldered directly to the DF player. They have a good sound quality and are able to play on high volume. This is important because the sound they play has to be audible from inside of the steel-case and against the surrounding noises in the bar environment.

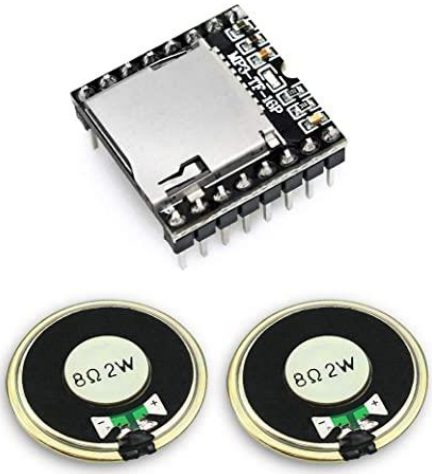

Figure 3-3: DF player with Speakers (source: https://www.amazon.de/KeeYees-DFPlayer-Metallgeh%C3%A4use-Lautsprecher-Kompatibel/dp/B07X2CZZDJ)

3.2.2 Input components

The only direct interaction a user has with the device is by throwing in a cigarette butt. So, the device has to check if and when something is inserted. For this purpose, a photoelectric barrier is installed that gives out a signal if the light stream is cut. The photoelectric barrier contains a laser diode module and a photoresistor. The casing of the laser diode module is made of robust copper. It can withstand high temperatures. If the laser diode module is supplied with power, it constantly sends out a laser beam that aims for the photoresistor. Due to safety reasons, never look directly into the laser beam. The sensitivity of the photoresistor can be set by turning the screw on the integrated blue box. Thus, one can ensure that the photoelectric barrier notices if and only if the laser beam gets cut by a cigarette butt.

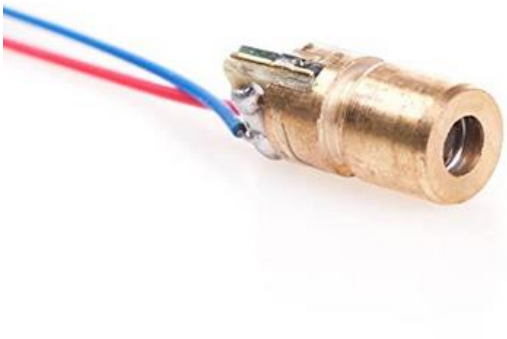

Figure 3-4: Laser (source: https://www.amazon.de/LAOMAO-650nm-Arduino-Raspberry-Prototyping/dp/B071JN3NQ8)

Figure 3-5: Photoresistor (source: https://www.az-delivery.de/products/foto-widerstand-photoresistor-licht-sensor-modul-ldr5528-1)

3.2.3 WiFi component

To connect the device with the internet, a NodeMCU Lolin V3 Module, a WiFi development board, is used. The module is an independent microcontroller running its own code. It is connected with the Arduino MEGA2560 for power supply via the 5V port as well as for data exchange via the RX-TX-ports. The module connects with the WiFi specified in the code, so an active WiFi signal is required. The module is programmed to send data to the Arduino-IoT-Cloud and receive data from it. To connect the module with a computer, a micro-USB data cable is required which is not included in this solution.

Figure 3-6: WiFi Development Board (source: https://www.amazon.de/AZDelivery-NodeMCU-ESP8266-ESP-12E-Development/dp/B074Q2WM1Y)

3.3 Software

To reach the three main goals (see Chapter 1), the software also contains the three stages plus additional supporting functionalities.

A big part of the gamification stage is the enjoyment of the unpredictable. By randomly changing games, visual and audible output, users do not know what they will see if they interact with the solution. Moreover, social influence is used to get people involved. By connecting the device with the internet, different ZigaRetters can exchange their data and create a competition between bars or cities. This competition can lead to a feeling of community and an emotional attachment to the device. So, the drive of people to make their own community better in a competition against another community is used here to get many people attracted. Then users will even invite their friends or bystanders to interact with the device. Furthermore, users get direct feedback on their actions with entertaining outputs and facts. That will manifest the idea of doing great by disposing of cigarette butts properly.

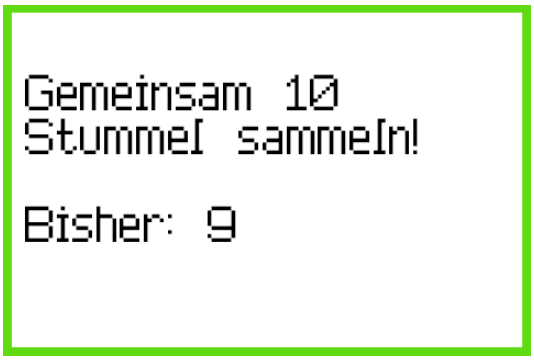

Figure 3-7: First stage – gamification

The second stage is the awareness phase. Because people are more likely to change their behavior if they are aware of the negative consequences their actions may have, a fact out of a list of facts about cigarette butt littering is randomly chosen and shown to the user. The list of facts we used can be found in the appendix (A1).

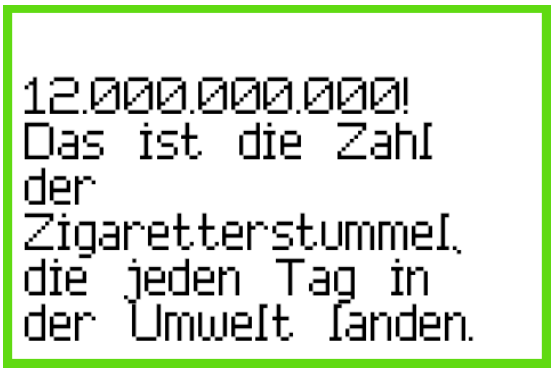

Figure 3-8: Second stage – facts

To give advice on how to behave better, in the last stage the ZigaRetter shows information on pocket ashtrays that can be used everywhere, anytime, and on the collecting system of TobaCycle. So, users see what they can change in their own behavior to stop cigarette butt littering and what they can advise friends, family or colleagues to make them behave more sustainably too.

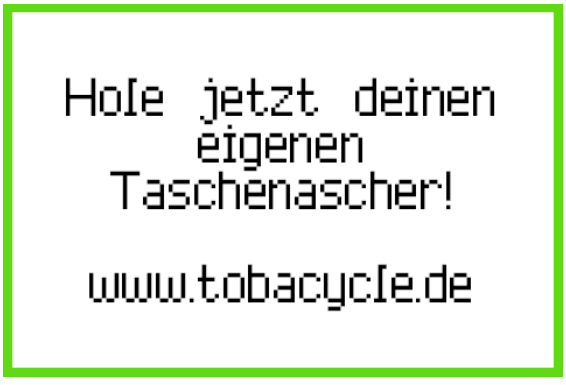

Figure 3-9: Third stage - action formation

To attract people that are currently smoking, every 30 minutes, the ZigaRetter uses its reminder function. By playing an engaging sound and showing searching eyes on the screen, bystanding smokers get interested in the device and will interact with it. Potentially, pedestrians passing by the device will be attracted too and could collect cigarette butts on the ground to interact with the device.
Additionally, the ZigaRetter stores the number of inserted cigarettes and is able to share this data with the Arduino-IoT-cloud. From there, other ZigaRetter linked with it can collect this data as input for their community games. Moreover, the data can be used to build a report on the savings the ZigaRetter network has.

4. Design files summary

All relevant design files needed to deploy and build our solution are listed in Table 1.

Design file name	File type	Open source license	Location of the file
Metal_Cutouts	.pdf	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Case/Metal_Cutouts.pdf
Technical_Drawing	.pdf	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Case/Technical_Drawing.pdf
Model_Case	.step	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Case/Model_Case.step
Model_Lid	.step	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Case/Model_Lid.step
ZigaRetter_Circuit	.jpg	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Circuit/ZigaRetter_Circuit.jpg
main	.ino	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Software%20Arduino/main.ino
images	.h	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Software%20Arduino/images.h
DFPlayer_Mini_MP3	.cpp	GPL v3.0	https://github.com/DFRobot/DFPlayer-Mini-mp3/blob/master/DFPlayer_Mini_Mp3/DFPlayer_Mini_Mp3.cpp
DFPlayer_Mini_MP3	.h	GPL v3.0	https://github.com/DFRobot/DFPlayer-Mini-mp3/blob/master/DFPlayer_Mini_Mp3/DFPlayer_Mini_Mp3.h
ZigaRetter_NodeMCU	.ino	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Software%20NodeMCU/ZigaRetter_NodeMCU.ino
arduino_secrets	.h	GPL v3.0	https://github.com/ZigaRetter/ZigaRetter/blob/main/Software%20NodeMCU/arduino_secrets.h
Audios	.mp3	CC	https://github.com/ZigaRetter/ZigaRetter/tree/main/Audios

Table 1: Design files

Metal_Cutouts: This document shows how to cut the sheet of stainless steel and where to bend it to build the case.

Technical_Drawing: This document gives the exact dimensions of the case for the replica.

Model_Case: This additional document can be used to get a 3D modelling of the case.

Model_Lid: This additional document can be used to get a 3D modelling of the lid.

ZigaRetter_Circuit: This document shows the exact circuit of all technical components.

main: This is the Arduino code to use in the open-source Software IDE and which has to be uploaded to the Arduino Mega 2560.

images: In this file are the byte arrays of the images loaded in the Arduino Software.

DFPlayer_Mini_MP3: This library is needed to use the DFPlayer Sound Module.

ZigaRetter_NodeMCU: This is the code to use in the open-source Software IDE and which has to be uploaded to the NodeMCU.

arduino_secrets: This is the file in which the WiFi credentials need to be written.

Audios: These are the sounds we used in the Arduino Software.

5. Bill of materials summary

The material list includes all parts needed to build a ZigaRetter. A list of recommended tools for assembly can be found under the material list.

Designator	Component	#	Cost per unit	Total cost	Source of materials
Case	Stainless steel (524mm x 340mm x 2mm)	1	31,76 €	31,76 €	https://www.metallparadies.de/edelstahlblech-k240-1-4-mm-staerke-bis-3-x-1-5-m.html
Case	Aluminium sheet (50mm x 100mm x 1mm)	1	2,74 €	2,74 €	https://www.metallparadies.de/alublech-0-8mm.html
Case	Acrylic glass (200mm x 200mm x 4mm)	1	3,43 €	3,43 €	https://www.amazon.de/Acrylglas-Zuschnitt-Plexiglas-Scheibe-transparent/dp/B07Q2Y2TSN/
Case	Combined sealing glue	1	5,99 €	5,99 €	https://www.amazon.de/Pattex-Universal-Kombination-Montagekleber-Fugendichtmasse/dp/B01I3IN54S
Case	Cylinder head bolts	4	0,03 €	0,12 €	DIY Store
Technical hardware	Metal angles	2	0,53 €	1,06 €	DIY store
Technical hardware	M3 x 5 screws	3	0,05 €	0,15 €	DIY store
Technical hardware	Arduino MEGA2560	1	35,49€	35,49€	https://www.amazon.de/Arduino-ATmega2560-Mikroprozessor-Datenblatt-REV3-Arduino-ard-a000067/dp/B00QAH9M06
Technical hardware	USB-A to USB-B cable (angled)	1	6,00 €	6,00 €	https://www.amazon.de/gewinkelt-m%C3%A4nnlich-rechts-90-Grad-Drucker/dp/B00L43167I/

Technical hardware	Power cable	1	2,14 €	2,14 €	https://de.aliexpress.com/item/4000554551262.html
Technical hardware	Normal pin header (20 pcs)	2	0,34 €	0,68 €	https://www.reichelt.de/stiftleisten-2-54-mm-1x20-gerade-mpe-087-1-020-p119888.html
Technical hardware	Curved pin header (20 pcs)	1	0,35 €	0,35 €	https://www.reichelt.de/de/de/20pol-stiftleiste-gewinkelt-rm-2-00-sl-1x20w-2-00-p51746.html?PROVID=2788&gclid=CjwKCAiAlrSPBhBaEiwAuLSDUNw1EPzrVEToIYbsdow0HtjWt0a2ab5soE7MENW0L5XwR35ahtDNbBoCDsIQAvD_BwE&&r=1
Technical hardware	Single basic-sided Perfboard	1	0,30 €	0,30 €	https://www.amazon.de/Doppelseitig-Prototype-Lochrasterplatte-Verschiedene-Kompatibel/dp/B0734XYJPM
Technical hardware	Jumper Wire Cable (7x M2M, 14x F2M, 4x F2F)	25	0,05 €	1,25 €	https://www.amazon.de/AZDelivery-Jumper-Arduino-Raspberry-Breadboard/dp/B074P726ZR/
Technical hardware	1K Ohm Resistor	1	0,02 €	0,02 €	https://www.amazon.de/AZDelivery-Widerst%C3%A4nde-Resistor-Widerstand-Sortiment/dp/B07Q87JZ9G
Input component	Laser Diode Module	1	1,00 €	1,00 €	https://www.amazon.de/LAOMAO-650nm-Arduino-Raspberry-Prototyping/dp/B071JN3NQ8
Input component	Photoresistor	1	1,66 €	1,66 €	https://www.az-delivery.de/products/foto-widerstand-photoresistor-licht-sensor-modul-ldr5528-1
Input component	Heat resistant tape	1	3,19 €	3,19 €	DIY Store
Output component	DF Player with 2 Speakers	1	6,99 €	6,99 €	https://www.amazon.de/KeeYees-DFPlayer-Metallgeh%C3%A4use-

					Lautsprecher-Kompatibel/dp/B07X2CZZDJ
Output component	3,5" TFT-LCD-Display	1	20,89 €	20,89 €	https://www.amazon.de/Anzeigemodul-TFT-LCD-Display-Modul-480x320-Arduino-Vorstand/dp/B07Y5Z6VZB
Output component	32GB SD Card	1	4,99 €	4,99 €	https://www.amazon.de/Intenso-Micro-Class-Speicherkarte-SD-Adapter/dp/B008XZO0IW
WiFi Component	NodeMCU v3 Lolin (WiFi Development Board)	1	5,33 €	5,33 €	https://www.amazon.de/AZDelivery-NodeMCU-ESP8266-ESP-12E-Development/dp/B074Q2WM1Y/
Total				135,53 €	

Table 2: Bill of Material

To build and connect the components or to install the components inside of the case, additional tools and materials are required. For example:

- Steel cutter
- Drilling machine
- Steel bender
- Welding machine
- Plier
- Soldering iron and wire
- Screwdrivers (various sizes)
- Superglue
- Double sided adhesive stripes
- Tape
- Plastic case
- Micro-USB cable
- Safety clothing and goggles

6. Build instructions

This section describes how to build a ZigaRetter step-by-step. Therefore, all individual components and their connections are described in detail.

6.1 Case

The material of the case is **stainless steel**, so that the device is safe for vandalism from the outside and fire from the inside. The case is bent and welded using the measurements in the **cutouts** (Appendix A2) and the **technical drawing** (Appendix A3). The specific measures of the lower element are dependent on the cigarette bin used to collect the cigarette butts. In this case, the design is tailored to the CITYC of TobaCycle. Because of licensing reasons, the exact measures of the bin are not included. For other bins, the lower part could have other sizes and the position of the screw holes could be different. The upper part is designed to be big enough to contain all the technical components needed and it is separated from the lower part, so the components are not exposed to a potential fire or smoke inside of the bin.
In order to get an ashtray, correct according to the technical drawing, we hired a professional. Anyone who dares to build the case himself should pay attention to general safety instructions. For example, the user is advised to **wear protective clothing and goggles**.
First, the stainless steel must be cut and drilled according to the dimensions given in the **cutouts** (Appendix A2) and the **technical drawing** (Appendix A3). With the help of a **steel bender**, the cutouts must then be bent along the black lines shown in the figures in Appendix A2. Afterwards, the bent elements must be welded with the help of a **welding device**. To complete the welding process, the bottom element of the case must still be welded to the bottom of the top element according to the distances in Appendix A3.
Then, with the help of a **drill**, it is necessary to drill holes for screws to be able to attach the lid to the back side of the case and mount the entire element on an ashtray. Furthermore, two holes should be drilled in the partition wall (bottom of the top element) so that the laser and the photoresistor can later be accommodated in the lower element.
Next, the **acrylic glass** should be attached from the inside behind the cutout in the upper element. To do this, it must first be cut to a suitable size. We recommend the dimensions 100mm x 120mm. To seal the acrylic glass to the case, **sealing glue** is needed, so the glass does not fall off and does not let in any fluids that could harm the technical components.
Finally, an **aluminium sheet** should be placed with some distance behind the insertion hole, so that cigarettes can be stubbed out. We also used **sealing glue** to consolidate it. However, we recommend this step after the installation of all electronics to facilitate the installation of the electronics.

Figure 6-1: Case that can be placed on an ashtray.

6.2 Technical Hardware

We recommend replicating the lower circuit in figure 6-2 to ensure the functioning of all electronic components. To use all technical components at the same time an Arduino Mega 2560 is needed. The corresponding plug connections can be seen in table 3. It is worth mentioning that the laser and photoresistor require a longer connection, which can also be easily disconnected in order to ultimately accommodate the elements in the case.

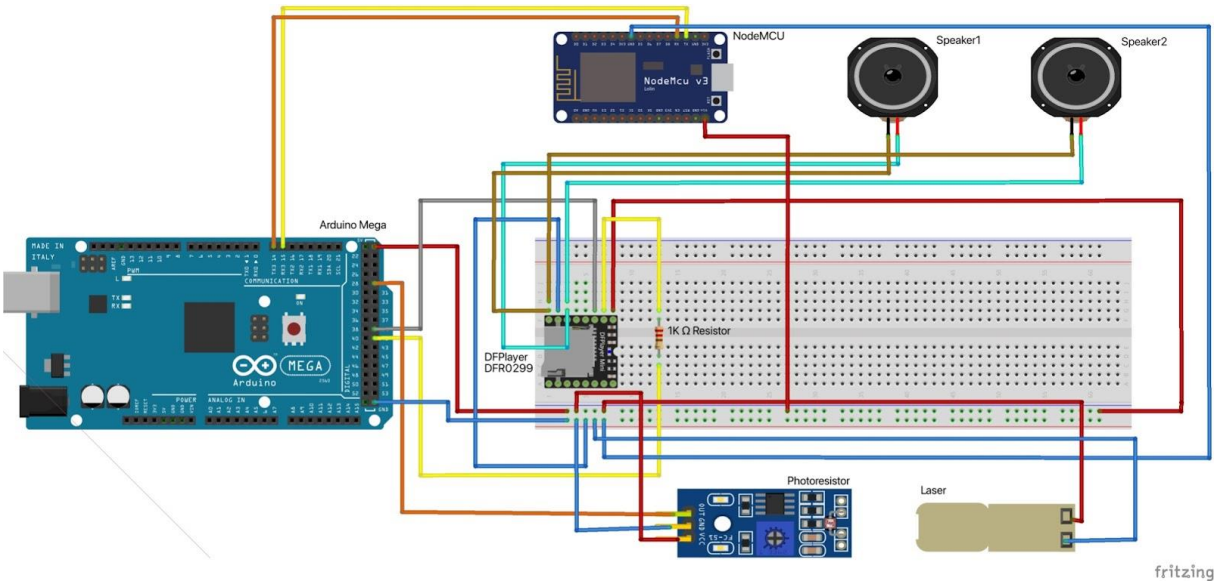

Figure 6-2: Arduino Circuit (Fritzing)

Component	M2M (Pins on both ends)	F2M (Just one Pin at one end)	F2F (No Pin)
Arduino Mega		2 (red and blue)	
NodeMCU		2 (yellow and orange)	2 (blue and red)
Speaker 1	2 (cyan and ocker)		
Speaker 2	2 (cyan and ocker)		
DFPlayer	1 (gray)	2 (red and blue)	
1K Ohm Resistor	2 (yellow and yellow)		
Photoresistor		4 (2x orange, 1x blue and 1x red)	2 (blue and red)
Laser		4 (2x blue and 2x red)	
Total:	**7**	**14**	**4**

Table 3: List of components and related types of cables

We used a single **basic-sided perfboard** instead of a breadboard to provide a more stable connection of the cables. If you also decide to use a single basic-sided perfboard, then you only have to solder the elements on the backside and copy the lines of a breadboard with solder. For soldering, we used a 48W digitally controlled soldering station at 350 degrees and 0.56mm solder wire (Pb 38, Sn 60, Cu 2). Please note that the row-lines of the 5V connector and the GND connector on a breadboard run in X-direction, which means that all pins in this row have the respective connector. To reproduce this on a perfboard, we used **normal pin headers** and soldered the whole row on the back of the perfboard. In the middle of the breadboard, however, the lines run in Y-axis, which means that we soldered the respective places on the back of the perfboard in Y-direction (see figure 6-3).

The recommended procedure:

1. Assemble components and tools.
2. Wear protective goggles.
3. Warm up the soldering iron.
4. Attach the 2x20 normal pin headers to the perfboard and apply solder to the whole row on the backside. **Note**: Solder must draw a line between the affected holes but is not allowed to include any other holes.
5. Attach DFPlayer to perfboard as shown in the circuit and clip off the protruding pins on the backside with a plier. Solder the respective pins to the respective hole. **Note**: Solder must cover the affected pin but is not allowed to be connected to other pins in X-direction (see figure 6-3).
6. Solder the ends of the M2M cables belonging to Speaker 1 and Speaker 2 according to the circuit.
7. Attach the remaining cables and the 1K Ohm resistor to the perfboard as shown in the circuit and cut off the protruding pins on the backside with pliers. Solder the respective pins to the respective hole. Make sure that you use the correct wires as shown in table 3. **Note**: Solder must cover the affected pin and the adjacent pins in Y-

direction but is not allowed to be connected to other pins in the X-direction. There must be a line in the Y-direction to ensure conduction (see figure 6-3).

8. Separate the curved pin headers into 1x18 pins and 1x2 pins.
9. Plug the 18 angled pins on the side of the Arduino Mega 2560 into the digital ports.
10. Plug the two angled pins on the Arduino Mega 2560 into the pins TX3 14 and RX3 15, so that the screen can still be easily attached to the Arduino Mega 2560 later.
11. Solder the corresponding cables to the respective angled pins according to the circuit (figure 6-2) and table 3.
12. Solder the cables from the laser to one red and one blue F2M cable each. Then take two more F2M cables and complete the connection according to the circuit.
13. Attach the remaining connectors to the respective components.
14. Use the supplied Arduino Mega 2560 case and attach the Arduino Mega 2560 using a screwdriver and M3 x 5 screws.
15. Plug the 3.5" TFT-LCD display directly onto the Arduino Mega 2560.
16. Plug the power cable and the USB-A to USB-B cable into the Arduino Mega 2560 to be able to load the software onto the Arduino later and to supply the system with power permanently.
17. Plug the Micro-USB cable into the NodeMCU v3 Lolin.

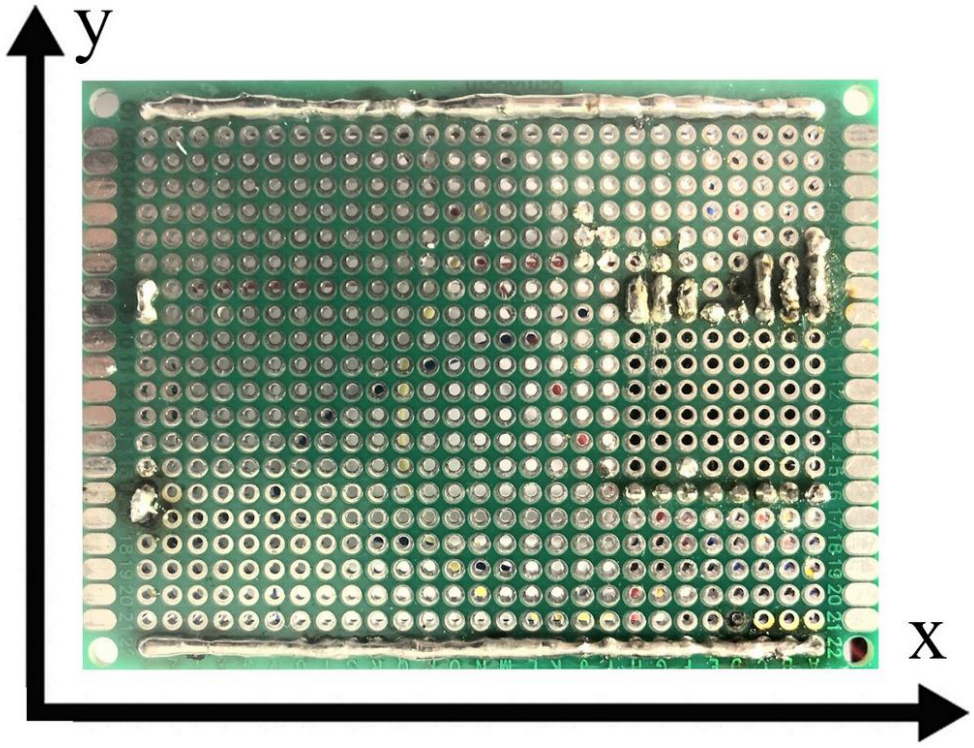

Figure 6-3: Perfboard with axis

6.3 Software

This section covers the upload of the firmware to the Arduino Mega 2560 and NodeMCU v3 Lolin, the creation of the Dashboard as well as the required settings in the software files. Beginning with the NodeMCU v3 Lolin:

1. Create a device on the Arduino IoT Cloud and select NoceMCU 1.0 under ESP8266 to set it up.
2. Create a Thing and add an integer variable. Then attach your device to it.
3. Generate a sketch and open it in the online editor.
4. Insert your WiFi credentials in the Secrets tab.
5. Replace the code in the .ino file with the code from ZigaRetter_NodeMCU.ino.
6. Replace the “countCologne” variable with the name of the integer you created in your Thing in the .ino file.
7. Upload the code to your NodeMCU v3 Lolin with the help of the Micro-USB cable.
8. Download Arduino IDE from Software | Arduino.
9. Install the Adafruit.GFX and MCUFRIEND_kbv library via the Library Manager in the Arduino IDE.
10. Arduino.h and SoftwareSerial.h should be installed by default. If not, download them in the Arduino Library Manager.
11. Download and copy both files from the DFPlayer_Mini_Mp3 library into your project folder.
12. Copy the code from the main.ino into your project.
13. Download and copy images.h into your project folder. This file contains the images. If you want to use your own images, you can use image2cpp (javl.github.io) to convert an image into a byte array. Use “horizontal - 1 byte per pixel” - draw mode and copy the code into images.h.
14. If you want to customize the messages, search for the use of “tft.print()” in your main code and change the messages.
15. Upload the code to your Arduino Mega 2560 with the help of the USB-A to USB-B cable.
16. Copy all .mp3 sounds from the audio folder to your microSD card. Make sure to format the microSD card to FAT32 beforehand. You can use your own sounds if you like. The order you copy the files to the microSD card determines the ID of the sound in the code. For example “mp3_play(3)” plays the third sound you copied to the microSD card.
17. Insert the microSD card into the DFPlayer Mini.
18. If you wish to create a dashboard, go to the Arduino IoT Cloud and create a new Dashboard. You can add a value and chart widget and connect it to the variable of your Thing.

6.4 Putting technical hardware into the case

Now it's time to put all the elements into the case. First, disconnect the F2M cables from the laser and photoresistor, and then insert the cables from the inside of the upper element of the case through the holes provided (figure 6-4 A).
Then reconnect the cables to the laser and photoresistor and cover them with heat resistant tape to minimize the risk of getting burned.
Afterwards place the laser in the lower element of the case just below the insertion hole and align it in the X-direction by using superglue. At this point, connect the system to power to detect the laser's point. **Safety Note**: For your own protection, please wear appropriate protection to prevent the laser from directly hitting your eye.
Then attach the photoresistor to the opposite side of the case with double-sided tape and align it so that the laser hits the photoresistor directly.
Note: Please make sure that the laser and photoresistor are not too deep below the insertion hole, as the entire case is still attached to an ashtray. If the elements are placed too deep, then a collision can occur when the ashtray and the case are put together. This could damage the laser and photoresistor.
After the superglue is completely dry, set the sensitivity of the photoresistor. The sensitivity of the photoresistor can be set by turning the screw on the integrated blue box. Considering that a signal should be triggered when a cigarette falls through the photoelectric barrier, simulate the speed of a falling cigarette with the screwdriver and watch if the LED on the element of the photoresistor is briefly interrupted. If this is the case, then the sensitivity is set correctly. Otherwise, this must be adjusted by turning the screw on the integrated blue box to the left or right.
Afterwards put the Arduino Mega 2560 with the 3.5" TFT-LCD display into the case and align it behind the acrylic glass and the cutout. To fix the position use two angles. One angle should be attached to the top of the case and the other to one side of the case. Both angles rest on the back of the case of the Arduino Mega 2560 (figure 6-4 B). The construct must then be fixed so that it cannot slip. We have used plenty of armor tape for this purpose. You can also use screws for this if you also drill suitable holes.
Then use double-sided tape to secure the two speakers inside the case (figure 6-4 C).
Next, place the Node MCU in its plastic case to prevent it from touching the metal and use double-sided tape to secure it in the ZigaRetter case (figure 6-4 D). Also tape the perfboard on the back of the Arduino case to prevent short circuits (figure 6-4 E).
The remaining cables should then be carefully placed in the case so that you can close the case easily.
Finally, the case can be carefully attached to the ashtray, but take care not to damage the laser and photoresistor.

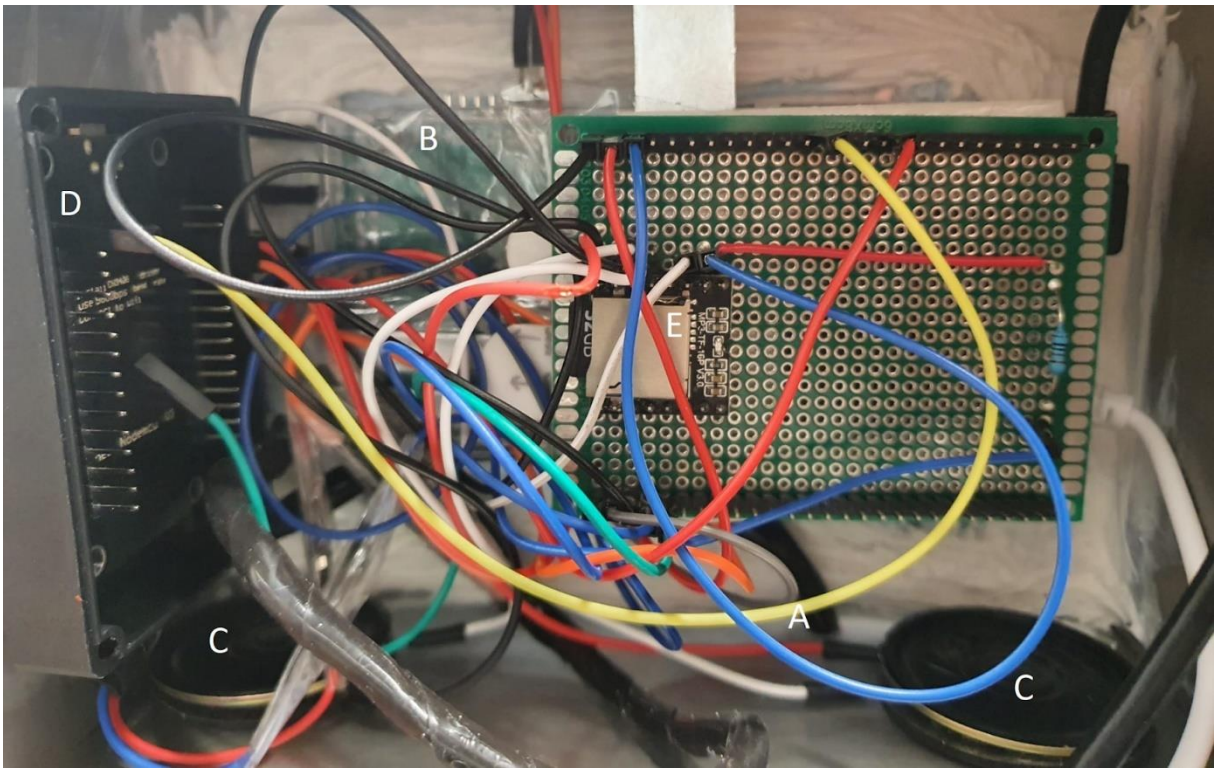

Figure 6-4: Technical hardware in the case

7. Operation instructions

This section provides instructions for the safe and proper operation of the ZigaRetter. Therefore, Bar Managers/Tenders and Smokers are addressed in particular, as ZigaRetter is intended for bars and Smokers are the users to be addressed.

7.1 Bar Managers / Tenders

In Order to install the ZigaRetter for usage in front of a bar, the following steps have to be fulfilled:

- Before setting the device up for the first time, make sure the WiFi settings are set correctly as described in chapter 6.3.
- Add the attachment to a fitting cigarette bin by placing it on top of the tube and fix it by screwing the four screws in the bottom part.
- Place the mounted device on a strategic place where it is seen by smokers in front of the bar and the staff can see it from inside, to secure it against vandalism.
- At last, provide the device with power through the attached power cable. If there is no socket available, an extension cord must be used.

The device will now operate as long as it is provided with power. To function properly, a stable WiFi connection is mandatory. After usage, just unplug the device from power. When the cigarette bin is full, it has to be emptied and the collected cigarette butts could be given to a recycling organization such as TobaCycle. The empty device can be stored on the inside or the outside, with or without the cigarette bin. Just make sure that the technical components are safe against rain, other liquids or theft.

7.2 Smokers/ Users

Smokers/ users interact with the device simply by throwing in their cigarette butts. After smoking they have to put their cigarettes into the insertion hole of the ZigaRetter. The attached aluminium sheet behind the insertion hole can be pushed to the back, so the cigarette will fall in. By pushing the cigarette against the aluminium sheet, still glowing cigarettes are pushed out. If the disposed cigarette butt is recognized by the photoelectric barrier, the outputs begin to do something. The user watches the three stages of output (see Chapter 1) and has nothing more to do. In the best case, users will talk with their friends and family about the device, the facts they learned about cigarette butt littering and recycling and collecting possibilities. May they act and buy a pocket ashtray.

8. Validation and characterization

The intention of the ZigaRetter is to attract, educate and nudge smokers in front of a bar, so that they change their cigarette butt littering behavior. Due to the Corona pandemic a validation of the ZigaRetter in a field test was not possible.
Nevertheless, we ran an artificially created field test with fellow students. The outer appearance of the device was found to be engaging and the interaction with the device was intuitive. The testers told us that the first stage of output was entertaining. They liked the sounds used and talked a lot about the possibilities of "cool" competitions between bars. Most of the students were shocked about several of the facts shown in the second stage. They were not aware of the negative consequences of cigarette butt littering, in particular because throwing cigarette butts on the ground is so common. The students who smoke wanted to know more about the pocket ashtrays and where to get them, so they could stop littering with their own cigarette butts. Some even wanted to have further information on how to participate in the collecting system of TobaCycle. Thus, in this artificial test environment, the ZigaRetter achieved good results. But to observe a significant effect of using the ZigaRetter on cigarette butt littering behavior, a greater study in a real field experiment has to be made.

9. Outlook and extensibility

The ZigaRetter has enormous potential for further development of itself and also for the TobaCycle ecosystem. Thus, the possibilities can be divided into the four areas of case, electronics, software and ecosystem.
First of all, the removable lid on the back of the case is very helpful for maintenance, but at this point it is still difficult because the electronic elements are fixed inside of the case and therefore need to be removed to be able to maintain it. After maintenance, everything has to be recalibrated in terms of screen and case cutout. This problem could be solved if the lower side of the removable lid, which goes inside the case, was deeper so that the electronic elements could be attached to it. Thus, if the electronic elements needed to be serviced, it would only be necessary to pull out the deeper lid on the back of the case to get all the electronics out as well. Second, currently the laser and photoresistor are inside the actual ashtray, which also contains the cigarette butts. In order to carry out the idea of separated parts between the ashtray and the electronics, and thus not further expose the laser and photoresistor to the dangers of potential fire, an ashtray could be built that has a second shell with a hollow space in between. The laser and receiver could then be placed in this intermediate space, with a small hole on either side of the laser and receiver still allowing it to function.
Third, more electronic elements could be added. For example, additional LEDs could enable a party mode. So when a milestone has been reached, such as a total of 100 cigarettes have been collected, a party mode provides colorful lights. In terms of gamification, this is a surprise and provides enjoyment and can increase the sense of community.
Furthermore, more games could be added. For example, by placing more ZigaRetter at different locations, a comparison could be made between them to establish a kind of competition, which in turn promotes a sense of community at a location and thus motivates smokers to properly dispose of their cigarette butts.
Additionally, it could be considered if future versions of ZigaRetter are based on a Raspberry Pi instead of an Arduino to increase the performance of the software. This could enable better graphical elements and more games. However, this still requires further investigation.
Since the ZigaRetter is also intended to encourage smokers to buy a pocket ashtray in order to promote the proper disposal of cigarette butts regardless of location, partnerships could also be established with bars or nearby kiosks that sell the pocket ashtrays. This would shorten the distance between advertising for pocket ashtrays and actual sales, as it would probably encourage more smokers to buy a pocket ashtray directly.
Due to the Corona pandemic, it is currently not possible to test the ZigaRetter in a safe environment of bars. Thus, the question remains whether the desired effect of the ZigaRetter actually occurs. In future work this could be checked to find out the actual effect and to identify further optimization potentials.

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Appendix:

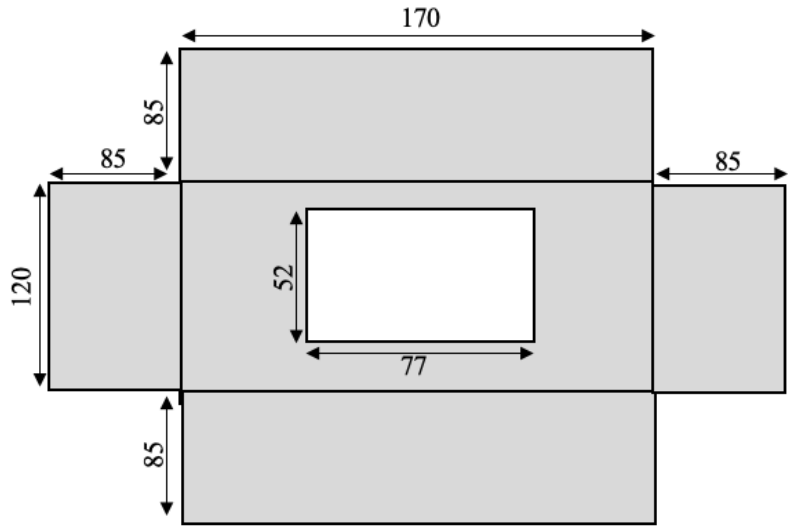
A1: Potential Facts

In the following you can find potential facts that can be shown on the device for awareness purposes. They are written in German because the target audience for this device are smoking young adults in Cologne that frequent a bar.

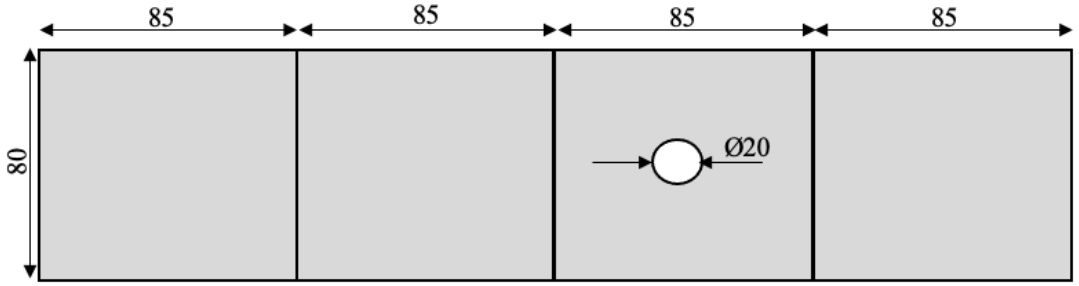
- Pro Zigarettenstummel gelangen 2 bis 6 mg Nikotin ins Regenwasser (Patel, Thomson, & Wilson, 2013).
- Eine Kippe vergiftet bis zu 60 Liter Grundwasser (Naturschutzbund Österreich, 2020).
- Zigarettenstummel töten Fische in Seen und Flüssen (Kolenda et al., 2019).
- Zigarettenstummel brauchen in Salzwasser 100 bis 400 Jahre, um sich zu zersetzen (Naturschutzbund Österreich, 2020).
- Zigarettenstummel sind 10 bis 15 Jahre in der freien Natur giftig (Naturschutzbund Österreich, 2020).
- Zigarettenstummel sind mit 30 bis 40 Prozent der häufigste Müll an Stränden und in Städten (Slaughter et al., 2011).
- In Zigarettenstummeln sind bis zu 7000 Schadstoffe enthalten (WHO, 2015).
- Zwei Drittel der Zigaretten in Deutschland landen auf dem Boden (WHO, 2015).
- Zigarettenfilter sind aus Kunststoff. Sie werden nicht abgebaut, sondern enden als Mikroplastik (Kolenda et al., 2019).
- 580 Mrd. Kippen landen EU-weit jährlich in der Umwelt (WHO, 2015).
- 12.000.000.000! Das ist die Zahl der Zigarettenstummel, die jeden Tag in der Umwelt landen (Slaughter et al., 2011).
- In Köln werden täglich 260 kg Zigarettenstummel weggeworfen (Statistisches Bundesamt, 2021).

A2: Cutouts

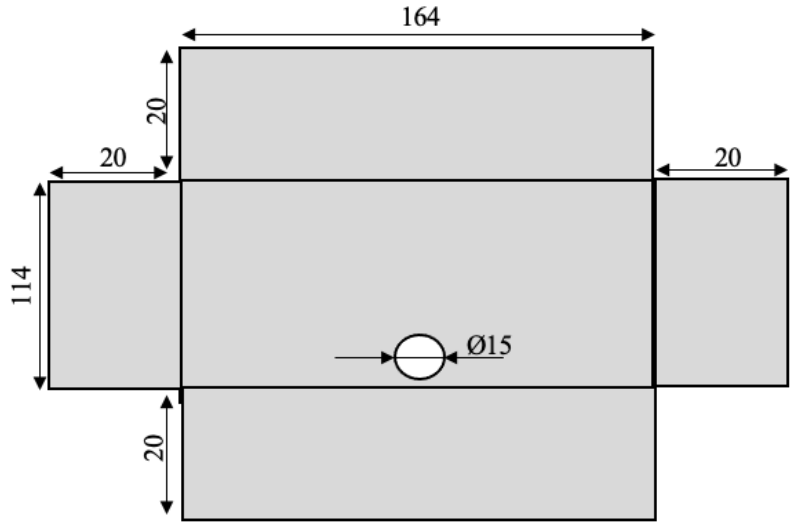
Cutout for the upper element:



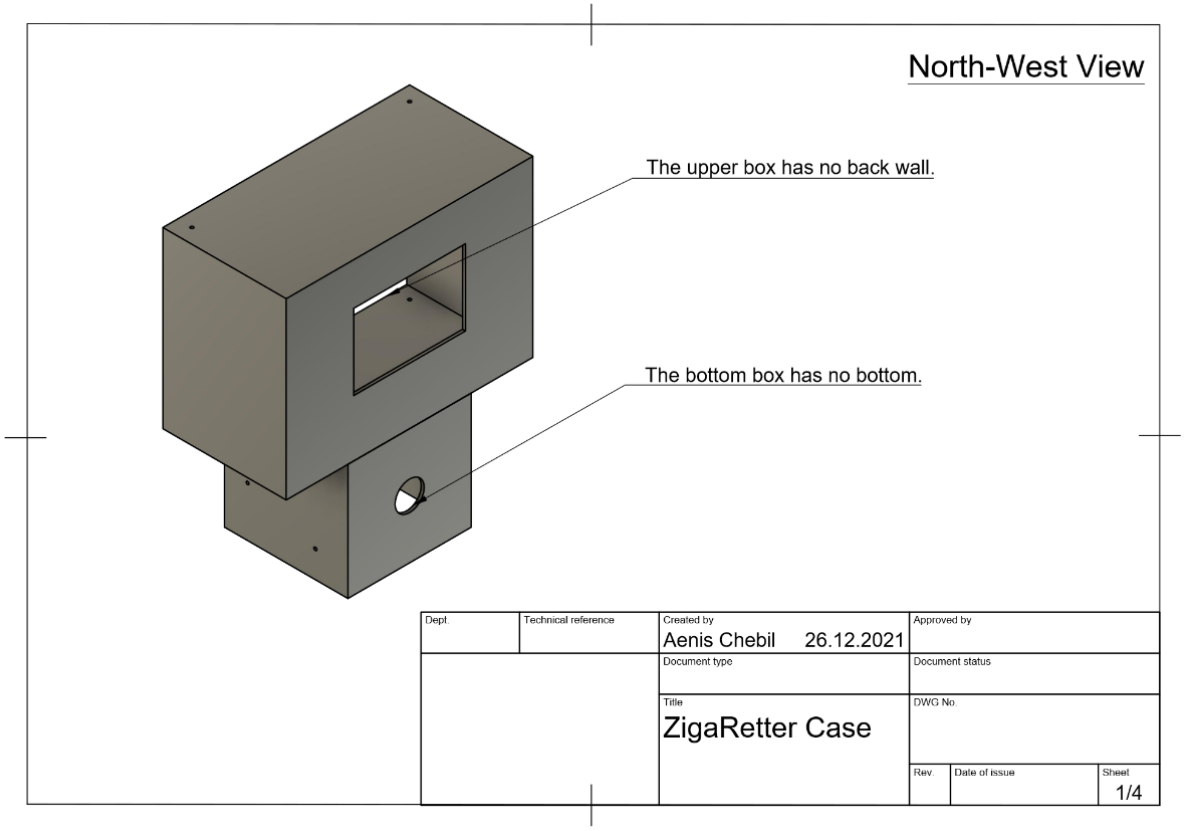
Cutout for the lower element:

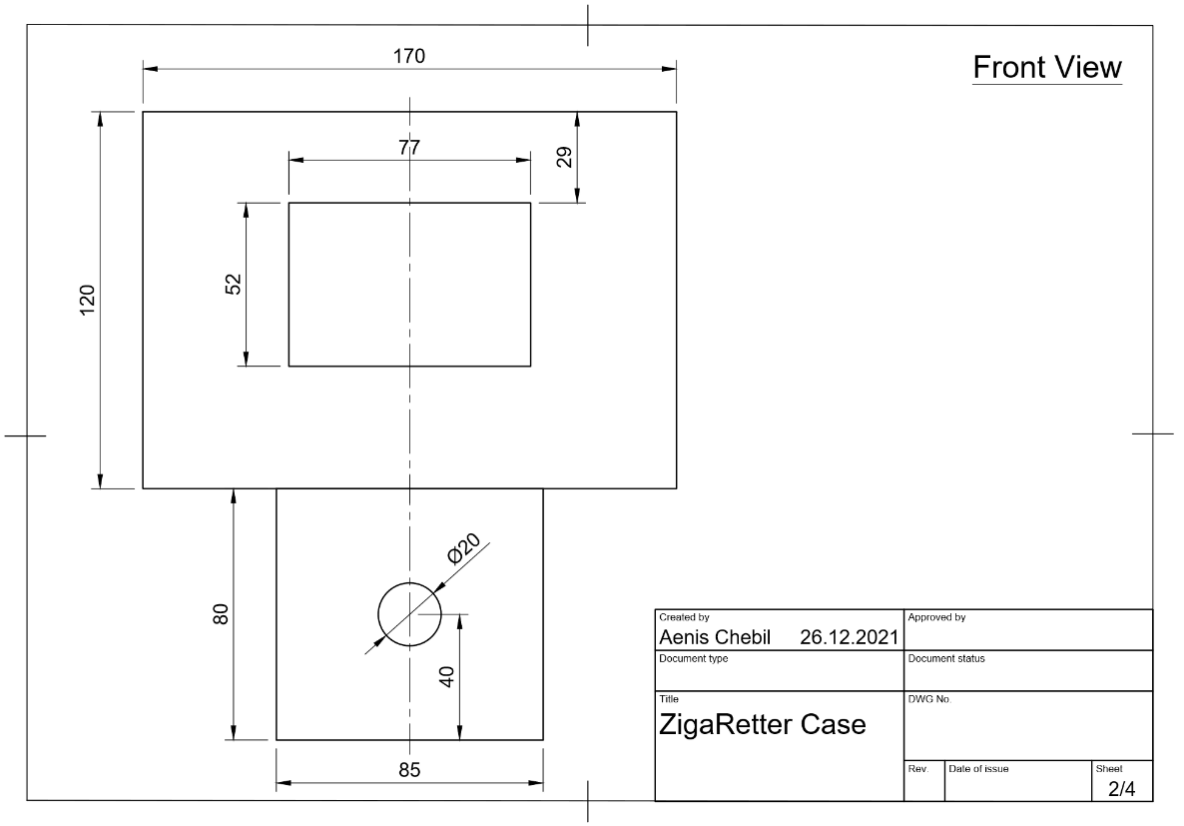


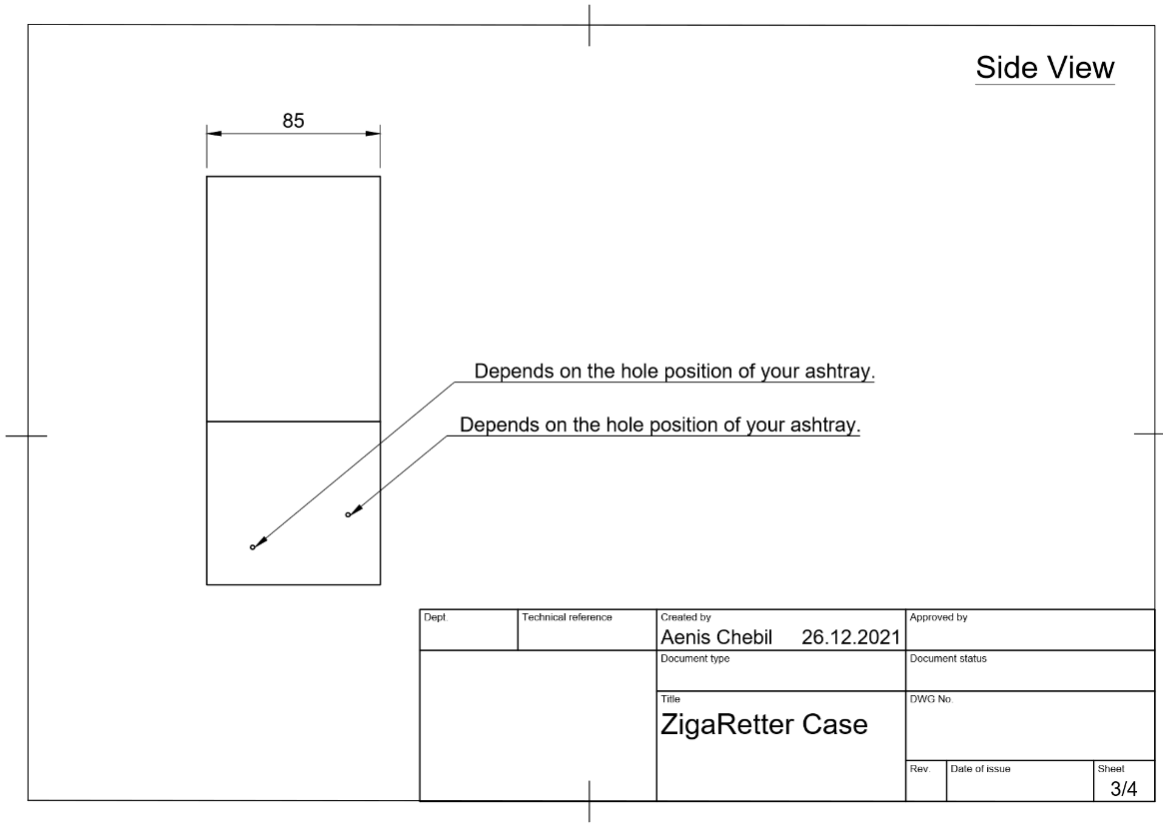
Cutout for the lid:



A3: Technical Drawing






Side View
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Depends on the hole position of your ashtray.
Depends on the hole position of your ashtray.
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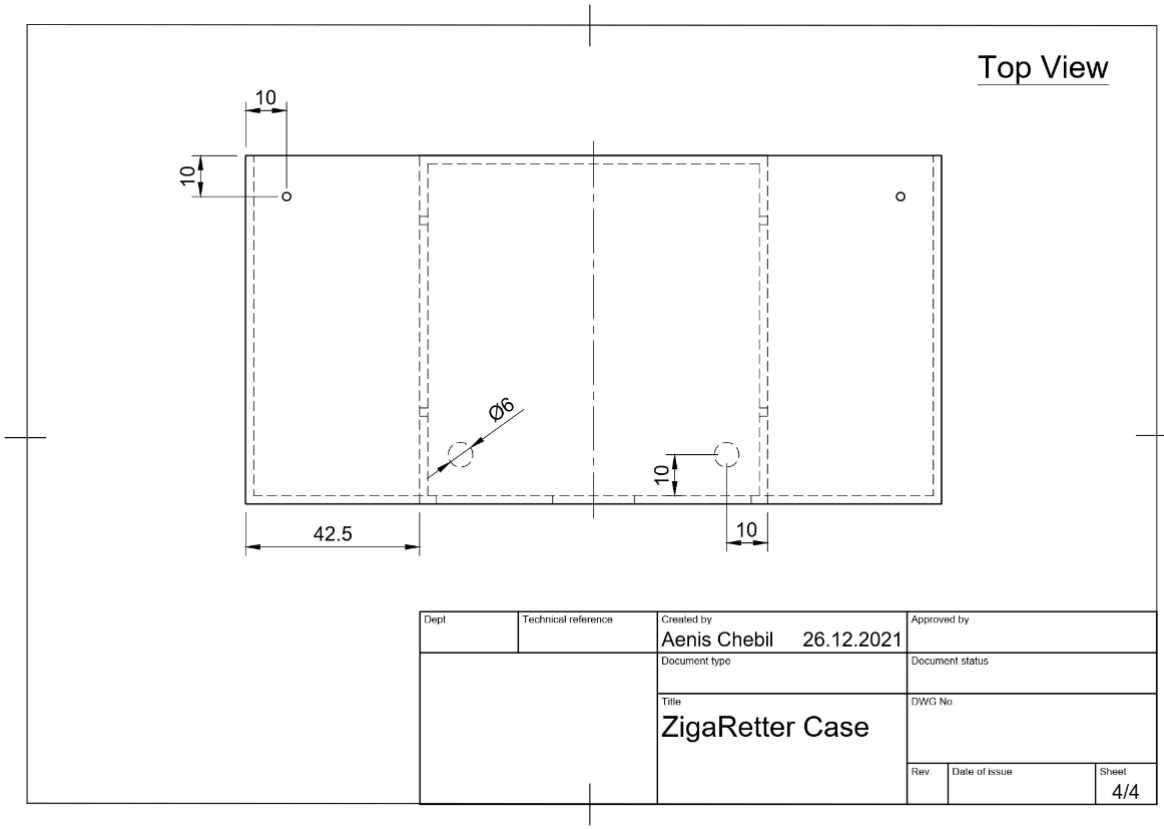
Top View
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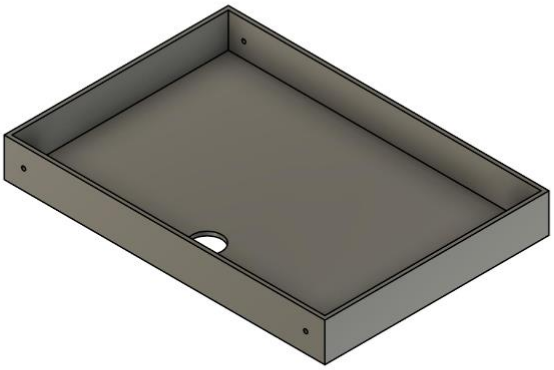
North-West View



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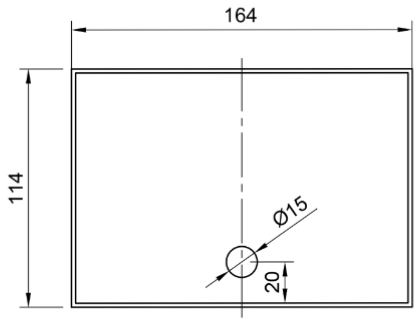
Front View



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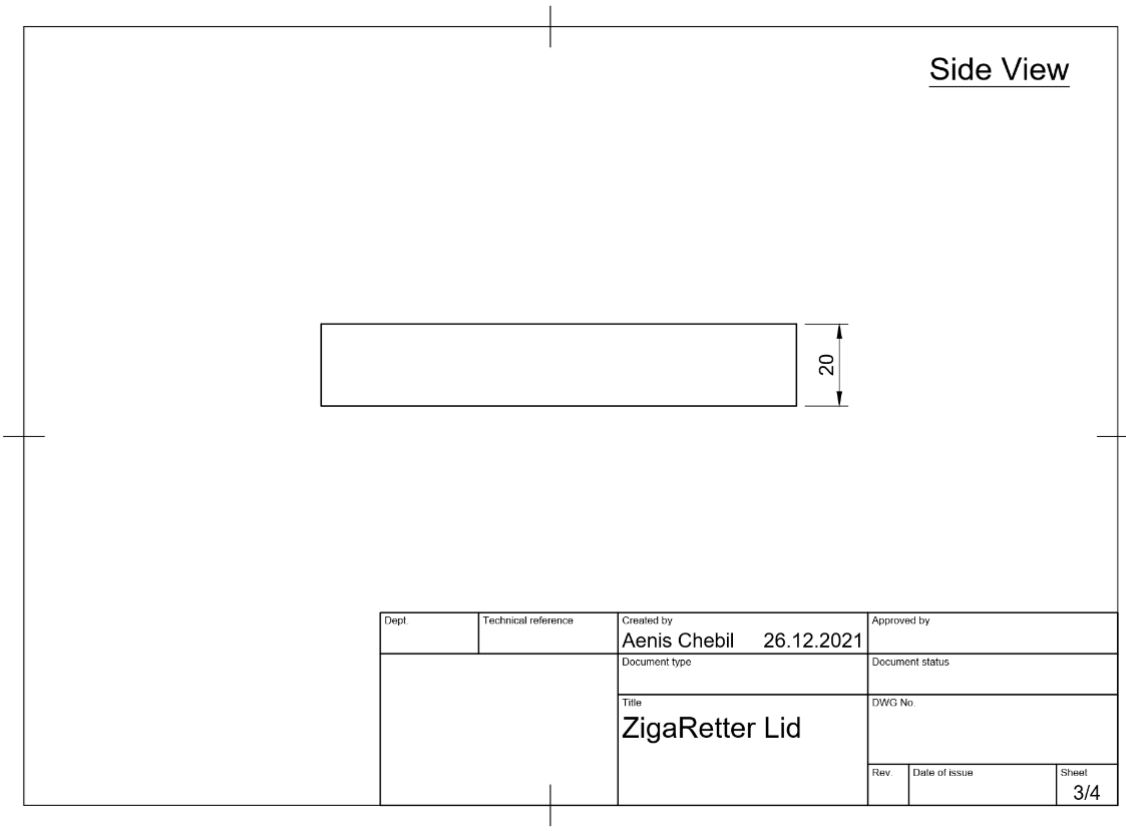
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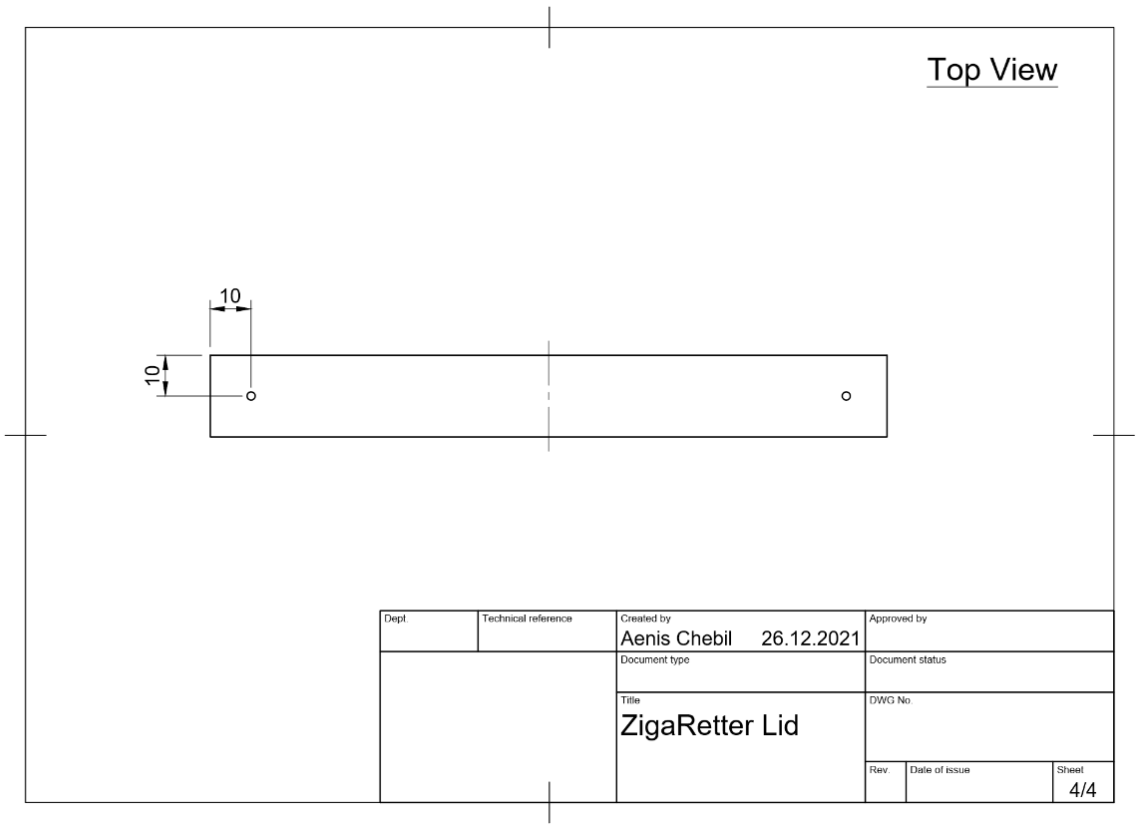
Top View
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DWG No.
Rev.
Date of issue
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