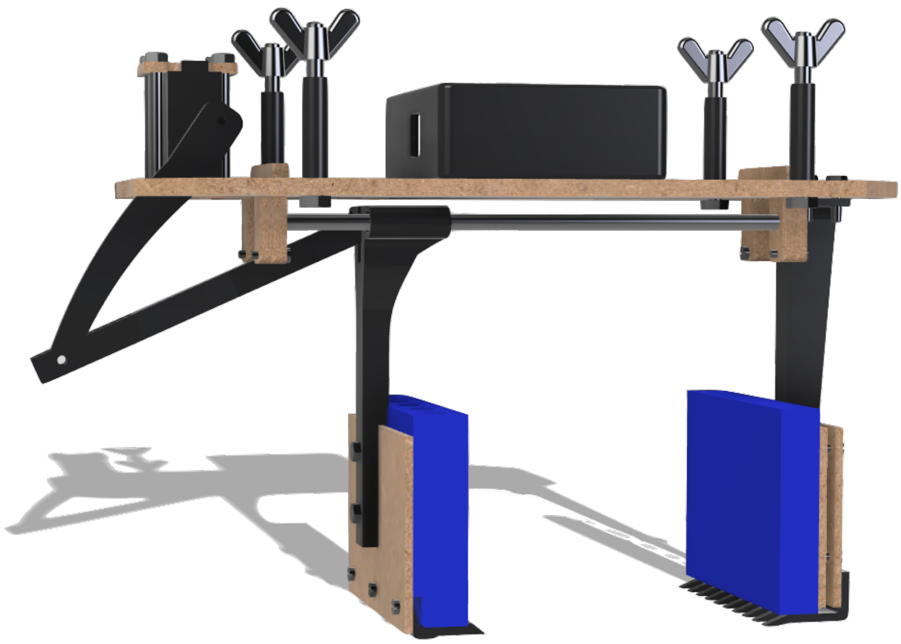
Engineering Drawings

ME-320 Product Development and Engineering Design



Group 42

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Bill-of Materials

Mechanical Components

Part Name	Part Description/ Purpose/Type	Quantity	Material	Production Process/Method	Cost per piece (CHF)	Weight (g)
Sol	Structural part connecting all other components	1	MDF (6mm)	Laser-cutting	0,45	0
Connection to fixed plain	Connection for the fixed plane	1	PLA	3D-printing	0,65	12,49
Connection to moving plain	Connection for the moving plane	1	PLA	3D-printing	0,79	15,8
Palier_Lisse	Plain bearing	4	PLA	3D-printing	0,185	0,37
Alu_bars	Aluminum rod	2	Aluminum (200 mm)	Cut to desired length by a hand saw	0,3	0
Bielle_1	Connecting rod attached to servo	1	PLA	3D-printing	0,25	5
Bielle_2	Connecting rod attached to the PinceMV	1	PLA	3D-printing	0,31	6,2
Plain_surf_1	Fixed plain surface for gripping		MDF (3mm)	Laser-cutting	0,05	0
Plain_surf_2	Fixed plain surface behind the gripping one	1	MDF (3mm)	Laser-cutting	0,05	0
Plain_surf_3	Moving plane surface for gripping	1	MDF (3mm)	Laser-cutting	0,05	0
Raclette Fix	Serve to scoop and grip	1	PETG	3D-printing	0,5	10
Raclette Moving	Serve to scoop and grip	1	PETG	3D-printing	0,45	8,8
Sponge	Sponges	2	Synthetic materials	Cut by hand	0,8	0
-	Bolts	1	Steel alloy	-	3	0
-	Screws	1	Steel alloy	-	1	0
Elec_Box	Electronic Box (housing all electronic components)	1	PLA	3D-printing	2,19	55
Servo_Blocking	Part Servo blocking the servo from the top	1	MDF (6mm)	Laser-cutting	0,02	0
Rods_attach	Part for attaching the alum. rods to the “sol”	2	MDF (6mm)	Laser-cutting	0,04	0
Tube		4	PETG	3D-printing	0,075	1,5
Other (alu_blocking)	**Note: all other smaller structural components**	1	MDF	Laser-cutting	0,01	9
					TOTAL Cost	TOTAL Weight (g)
					13,04	124,16

Note: The weight of the MDF is not shown. Laser-cutting MDF always requires taking some margins, therefore, precise weight is not calculated. This table includes the final assembly materials but uniquely the mechanical components. In another table are presented the electrical components with their type and costs.
Furthermore, the budget on the “Team Budget” sheet does not necessarily match the above-mentioned prices. Above we have included only the prices of pieces that were included in the final design and assembly.

Figure 1: Bill of Materials

Bill of Electronics Materials

Part Name	Part Description/ Purpose/Type	Quantity	Material	Production Process/Method	Cost per piece	Total Cost
Electronics cable	Cables (0.30/m)				2,00 CHF	
Bernier serre fils	To connect cables going out of the strip board	3			0,25 CHF	
Wagon connector 222	To connect easily the external component to the board	2			0,40 CHF	Only used for prototyping
Capacitor	Metal detection	1			0,20 CHF	
Strip board	Improved stability of the electronic circuit	0,25			7,00 CHF	
						Total Cost = 5,5 CHF

Figure 2: Electrical Bill

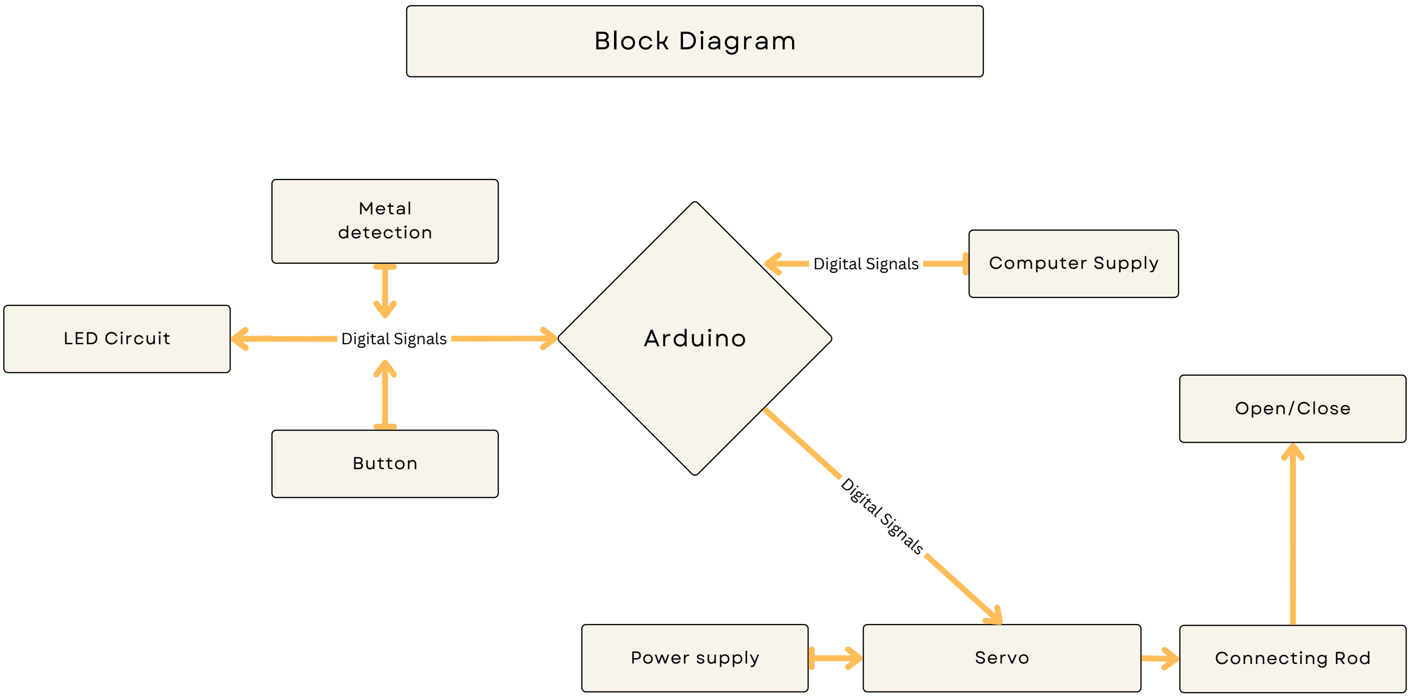
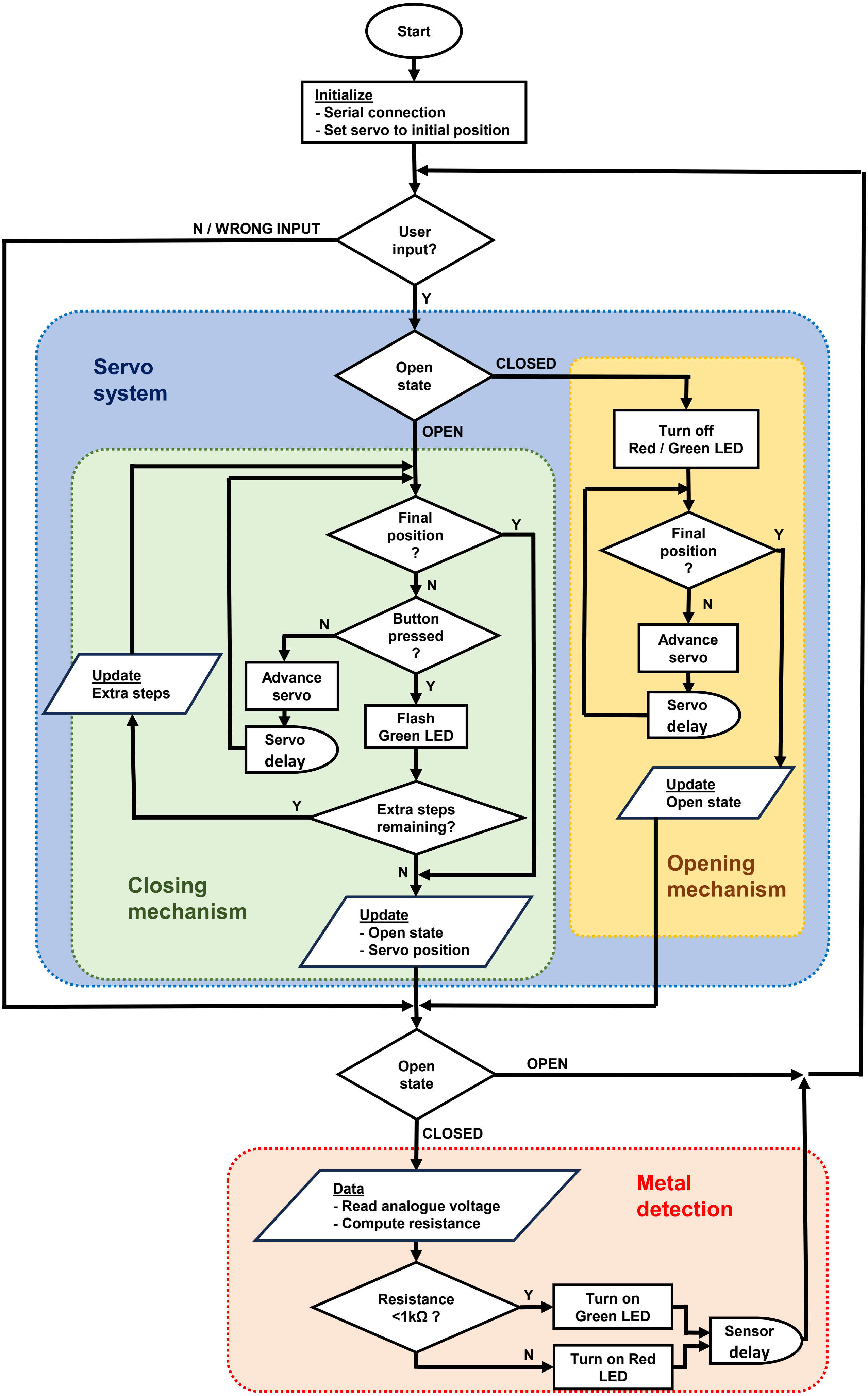
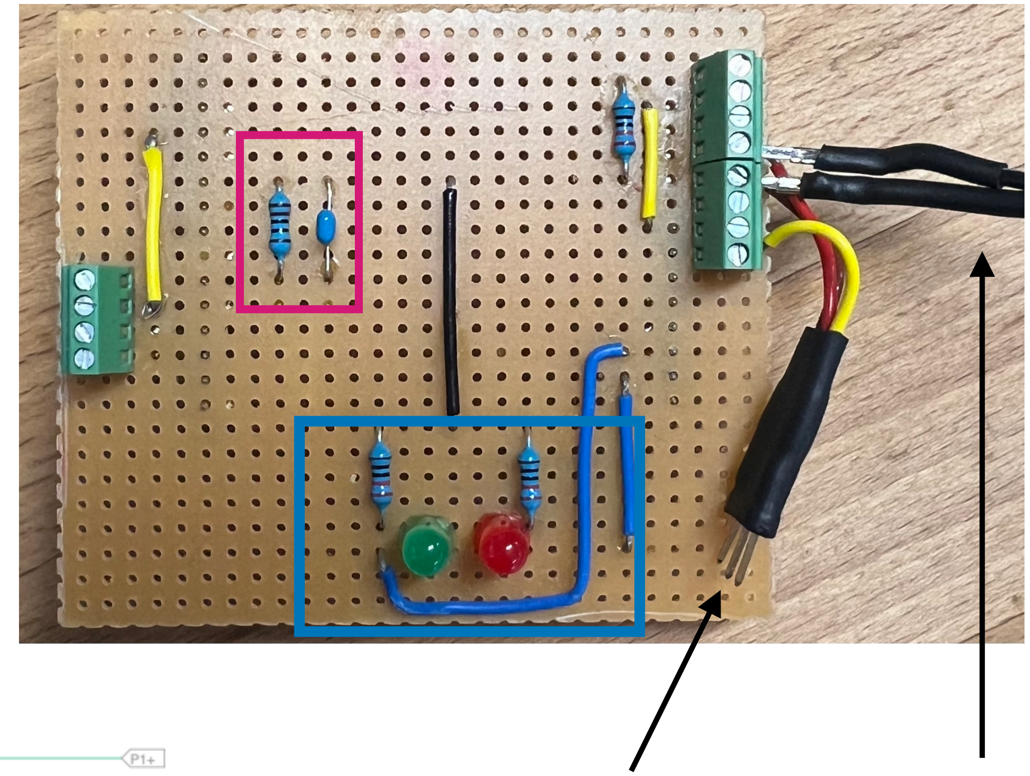
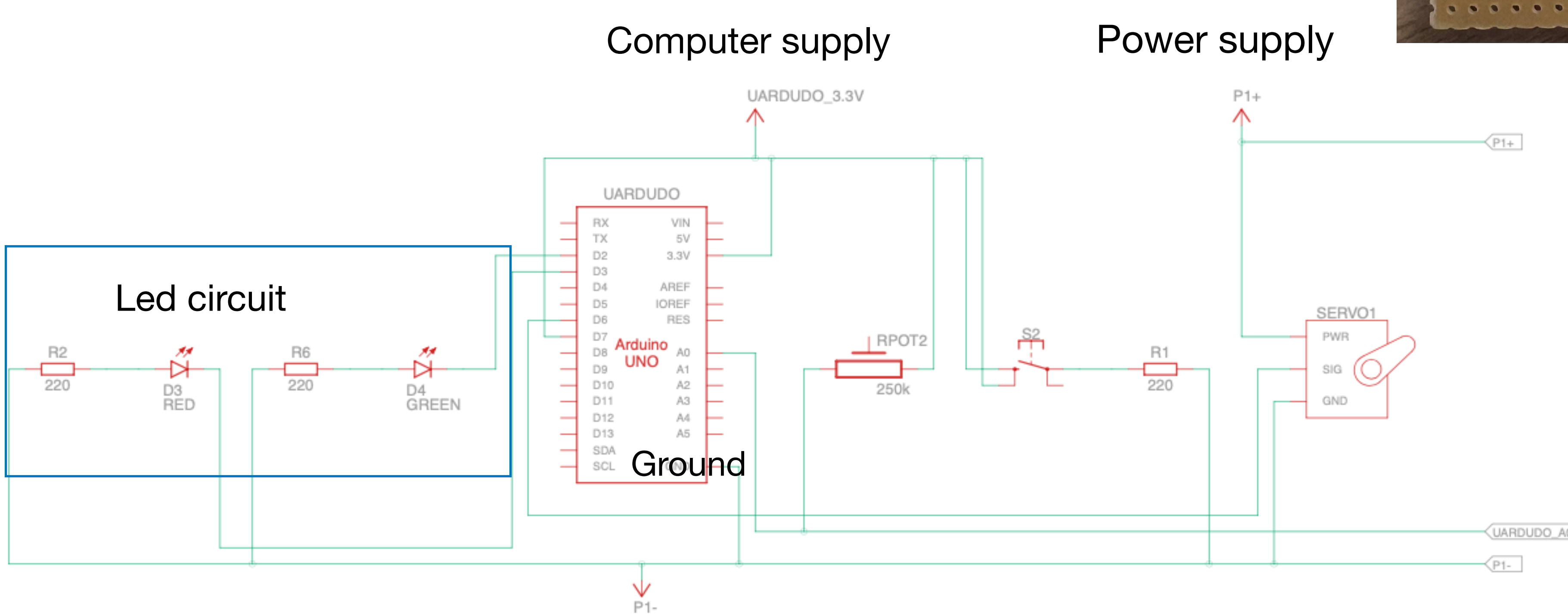


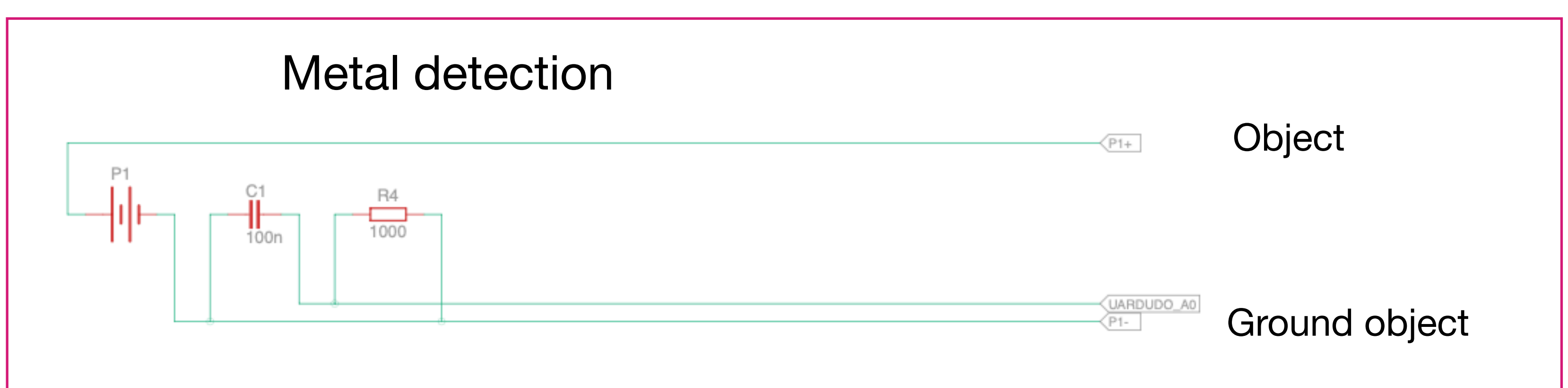
Figure 3: Block Diagram

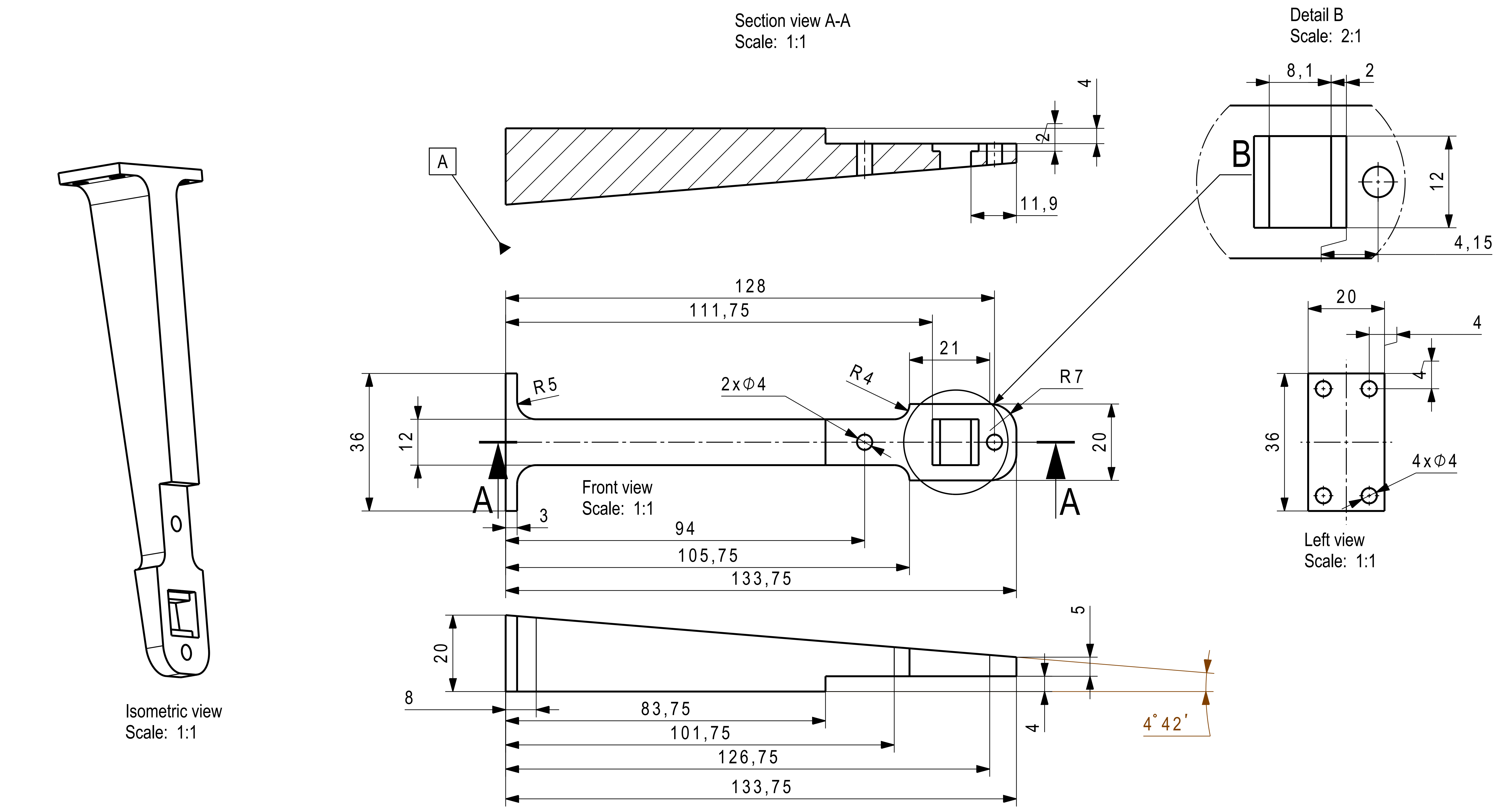

Start
Initialize
- Serial connection
- Set servo to initial position
User input?
N / WRONG INPUT
Y
Servo system
Open state
CLOSED
OPEN
Turn off Red / Green LED
Final position ?
Y
N
Button pressed ?
N
Y
Advance servo
Servo delay
Flash Green LED
Update Extra steps
Extra steps remaining?
Y
N
Update
- Open state
- Servo position
Closing mechanism
Final position ?
Y
N
Advance servo
Servo delay
Update Open state
Opening mechanism
Open state
OPEN
CLOSED
Metal detection
Data
- Read analogue voltage
- Compute resistance
Resistance <1kΩ ?
Y
N
Turn on Green LED
Turn on Red LED
Sensor delay

Circuit schematic









This part serves to attach the fixed plane that grips objects to the rest of the structure. On the bottom there is a placement for the button. On top, the piece is attached with 4 screws to the structure.

DESIGNED BY:	R. Zürcher
DATE:	23/11/2023
Weight	12.49 g
SIZE	A3
SCALE	1:1
Material	PLA
DRAWING NAME	Connection to fixed plain
SHEET	1/1

Production Method: 3D Printing

EPFL Product development and engineering design

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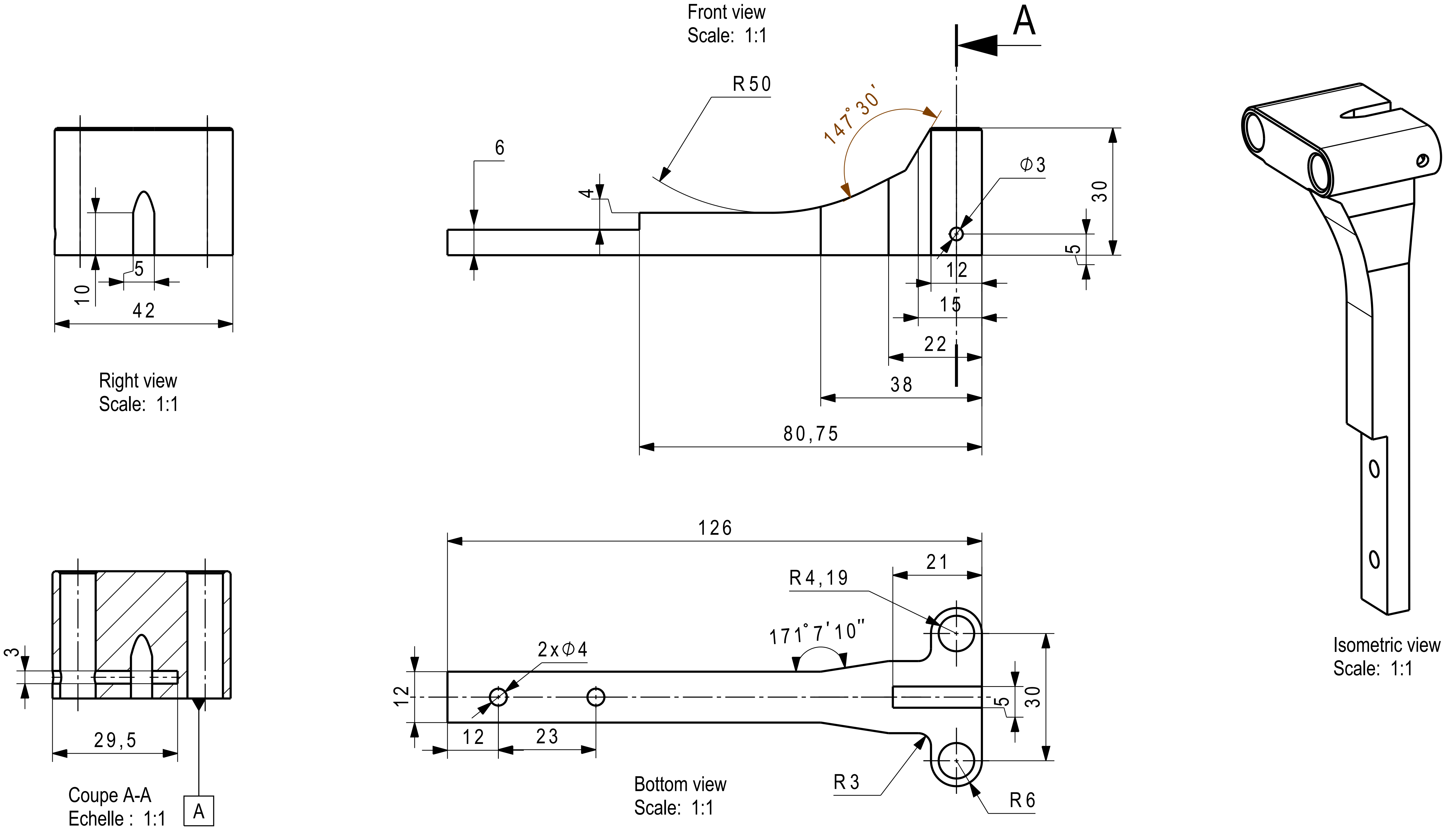

This part is designed to slide on top of plain bearings, and is also connected to the plane surface that is gripping the objects. This piece slides on the 2 aluminium bars in a linear motion, driven by the connecting rod. It is attached by a pin to the connecting rod mechanism.

DESIGNED BY: R. Zürcher		Production Method: 3D printing		
DATE: 17/12/2023				
Weight: 15.8 g				
SIZE A3		EPFL Product development and engineering design		
SCALE 1:1	Material PLA	DRAWING NAME Connection to moving plain		SHEET 1/1

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I	_
H	_
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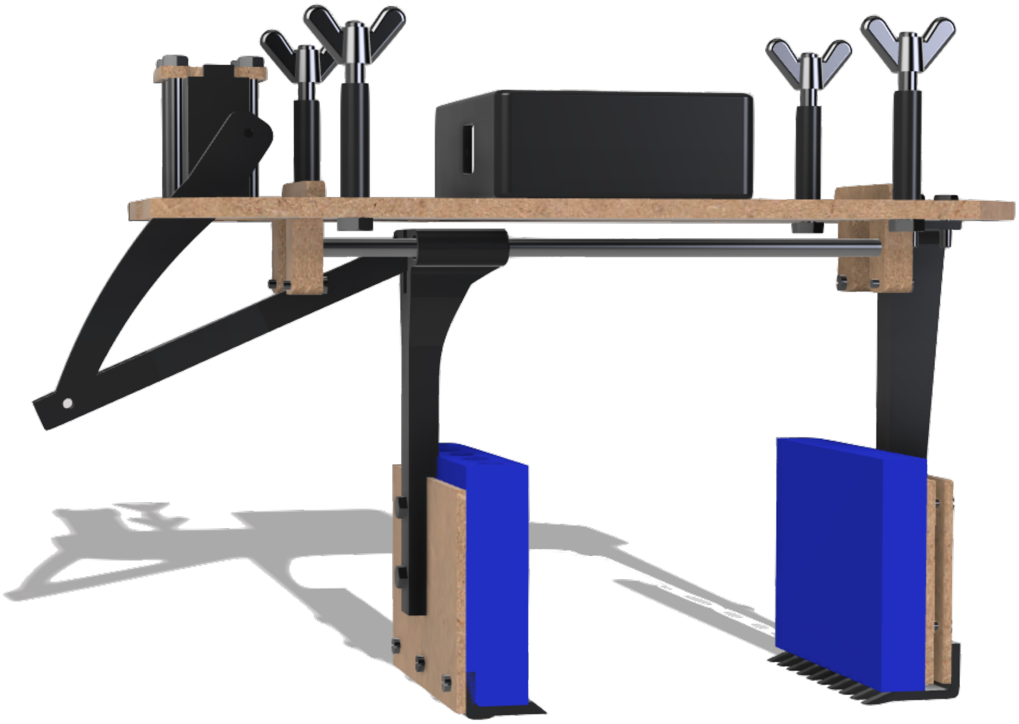
C	_
B	_
A	17.12.2023

Final Report

ME-320 Product Development and Engineering Design



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EPFL

1 Summary of the approach

Our final design consists of a connecting rod mechanism, driven by a servo that closes two parallel surfaces, which grip objects. One of them is fixed to the entire structure and is stationary, with two sensors attached to it. The other moves in a linear motion, driven by the connecting rod and guided by two parallel aluminum rods. The 3D-printed part that slides on the rods has 4 integrated plain bearings.

We have chosen a connecting rod mechanism because of its simplicity and robustness. There are very few moving parts, transforming rotation into a linear motion, overall it is a reliable design. We use two 3D printed levers, each one of around 110 mm in length, allowing our mechanism to open and close for a total of 20 cm. The two parallel rods guide the linear motion and the plain bearings ensure reduced friction between the aluminum and 3D printed parts. We have tried using both a servo and DC motor, and after some consideration, decided to implement the former into our mechanism. The servo, although bulkier and having a 180-degree limitation, provides more torque, which in our case is necessary to ensure complete closure of the mechanism.
Furthermore, we have settled on using a connecting rod mechanism as it allows for a rapid opening and closing. It takes two seconds for an open-close cycle, which is a significant advantage when having a time limit for catching all objects. For comparison, an earlier prototype, using a rack and pinion mechanism, required 16 seconds per cycle. The main advantages of this setup are its compact design, reliability, fast response time, as well as simplicity of manufacture and operation.

Regarding the choice of sensors, our gripper has two types. One for detecting if the object is metallic or not, and another whose purpose is to stop the closing movement in case an object with bigger dimensions has been gripped. To detect the nature of the object, a resistance sensor is used. The sensor is composed on one end of two lengths of stripped flexible copper wire wrapped around the sponge, such that when the object is gripped it bridges the gap between the two wires. On the other end is a voltage divider which compares the voltage drop across the object to one across a known resistor, and sends the difference to the Arduino, allowing it to compute the resistance. If the objects resistance is lower than a threshold calibrated for the system (about 500 Ω), the green LED will turn on, indicating metal, otherwise the red LED will light up.
For the second sensor, we use a button that sits in the middle of the fixed plane. Four bolts with springs are used to hold a travelling secondary surface, which has the sponge attached to it, in a way that the button can be pressed no matter where the object is on the sponges surface. The springs help the secondary surface return to its original position and prevent the button from "sticking", they are also cut in a way that tunes the amount of force necessary to activate the button. The travel distance of this plane is only a few millimeters, so the metal detection wires are unhindered. This is necessary for objects which are too large for the gripper to close fully, so as not to damage the object or servo motor. We have chosen these sensors because of their ease of use and implementation, and have found them to be very reliable throughout our testing

Finally, the materials have been chosen carefully to meet the specific requirements of the gripper. The connecting rod mechanism is made of 3D-printed parts as some of the more elaborate pieces could not be laser-cut. We implement aluminum rods because of their rigidity and smooth finish, furthermore, their manufacturing was relatively simple, consisting of cutting the rods to length and polishing them. The rest is made of 4 or 6mm thick MDF cut on a laser cutter. This method provided a lot of flexibility during prototyping, and we have used it extensively because of the possibility to manufacture parts quickly at a low cost. Where it had not been possible to use MDF, we 3D-printed the parts using PLA. Most connections between parts are bolt and screw, with only a few places requiring glue. The main reasoning behind this has been that prototyping, testing and changing parts should be as easy as possible. On the other hand, fitting parts together perfectly requires more iterations and would have resulted in us going over budget.

2 Sustainability and Scalability

Out product is suitable for mass production, with some modifications. Most parts that are used are made of MDF (4 or 6mm thick). The 3D printed parts, such as the connecting rod mechanism, take a long time to be produced. Therefore, those parts could be created by alternative manufacturing methods such as injection molding or thermoforming. Thus, saving time and reducing manufacturing costs drastically. Furthermore, the sponges that had to be cut manually to the desired shape and size would be stamped in the right dimensions to fit our model, and the stripboard circuit would be replaced with a custom PCB.

The gripper's sustainability could be further improved by reducing the number of building components while retaining a modular design and having integrated parts, which will facilitate assembly, maintenance, repair, and eventual recycling. To conclude, utilizing recycled or eco-friendly materials for the gripper components will further enhance this aspect.

3 Reflection on the design

After completion of the proof of concept, we could fully analyse the advantages and drawbacks of our device. We have concluded that, although the gripper can easily handle small objects, if presented with an object that is large and heavy it could struggle to grab hold. Furthermore, the speed of the mechanism, which is advantageous in our case where time is an important factor, could be a potential drawback in situations where precision is required. Therefore, future improvements will feature higher torque when closing and more precise movements. Another aspect that was unexpected was the amount of prototyping that was required to make this design preform in a satisfying manner, as our initial design had different sensors, motor, and closing mechanism. Nevertheless, trial and error has turned out to be the best way to overcome obstacles and optimise the gripper's performance. To conclude, more sensors could be integrated, thus ensuring proper detection of object's nature, and a precise closure distance. For instance a camera could be implemented, allowing us to know precisely the dimensions of the object and plan the closing movement accordingly. Along with a software update, which could enable more specific object detection (e.g. type of food, type of cutlery, etc).

4 Litrature/Patent

Reference 1: Axiomatic Design of a Linear Motion Robotic Claw
Link: https://www.researchgate.net/figure/The-final-design-constrains-gripper-travel-using-a-pair-of-bearing-shafts_fig2_308922938

In this Publication we find a mechanism similar to the one we have implemented, the main differences being that the gripper is mounted horizontally whereas ours is vertical, and that this symmetric design has both grip surfaces in motion, which we cannot do due to our sensor and size requirements.

Reference 2: Novel-robotic-gripper
Link: https://www.researchgate.net/figure/Novel-robotic-gripper-actuated-with-a-slider-crank-mechanism-17_fig8_297691165

This design, which served as a reference point for our analysis, employs a gripping method that is distinct from our approach. We have equally considered using a three point grip, however our design ultimately diverged by opting for a simplified two-sided gripping system because of the need to pick up many small objects, such as seeds.

Reference 3: Dynamic Characteristics and Anti-slip Grasping
Link: https://www.frontiersin.org/articles/10.3389/fnbot.2021.684317/full

This publication inspired key elements of our gripper, despite certain deviations. Notably, our gripper features a single connecting rod as opposed to the dual connecting rods centered around the servo in the referenced model. Our gripper utilizes aluminum rods to guide linear movement, differing from the slider-based system described in the publication.