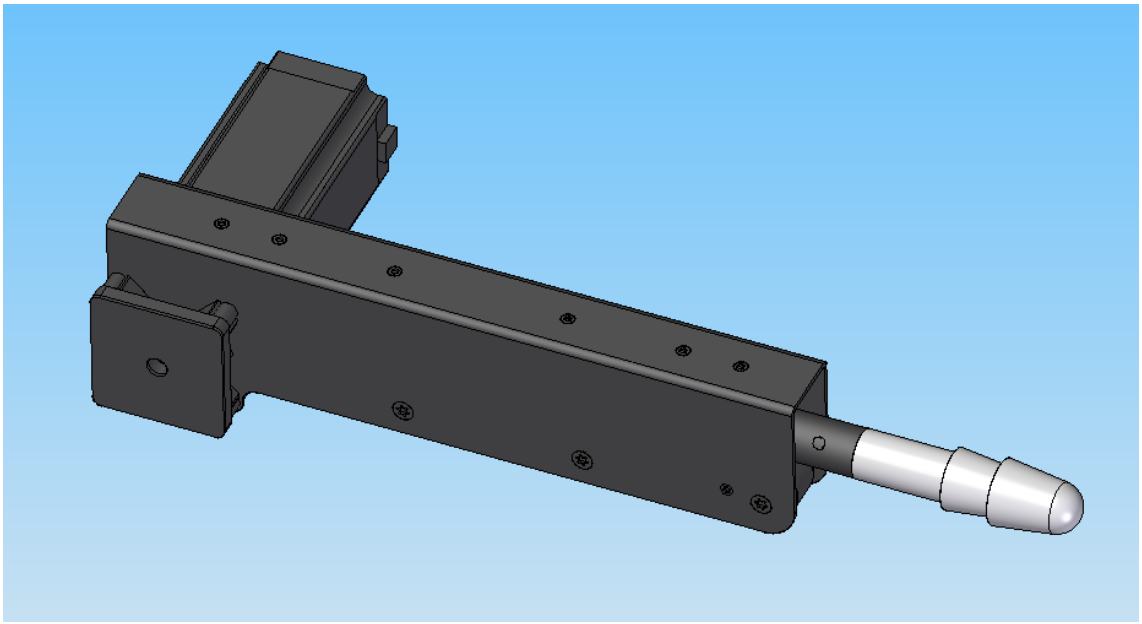
LM42P

Love(L) Machine(M) For(4) Two(2) People(P)



by an anonymous author

An open source document presenting
the LM42P

Lausanne

June 30, 2026

`lm42p.com`
`lovemachine42people@gmail.com`

Contents

Part I

DIY

LM42P cannot be held responsible for any malfunction of the machine that may result in injury. You use this machine entirely at your own risk and responsibility.

Below you will find information on how to obtain an **LM42P**. Currently, two variants are available:

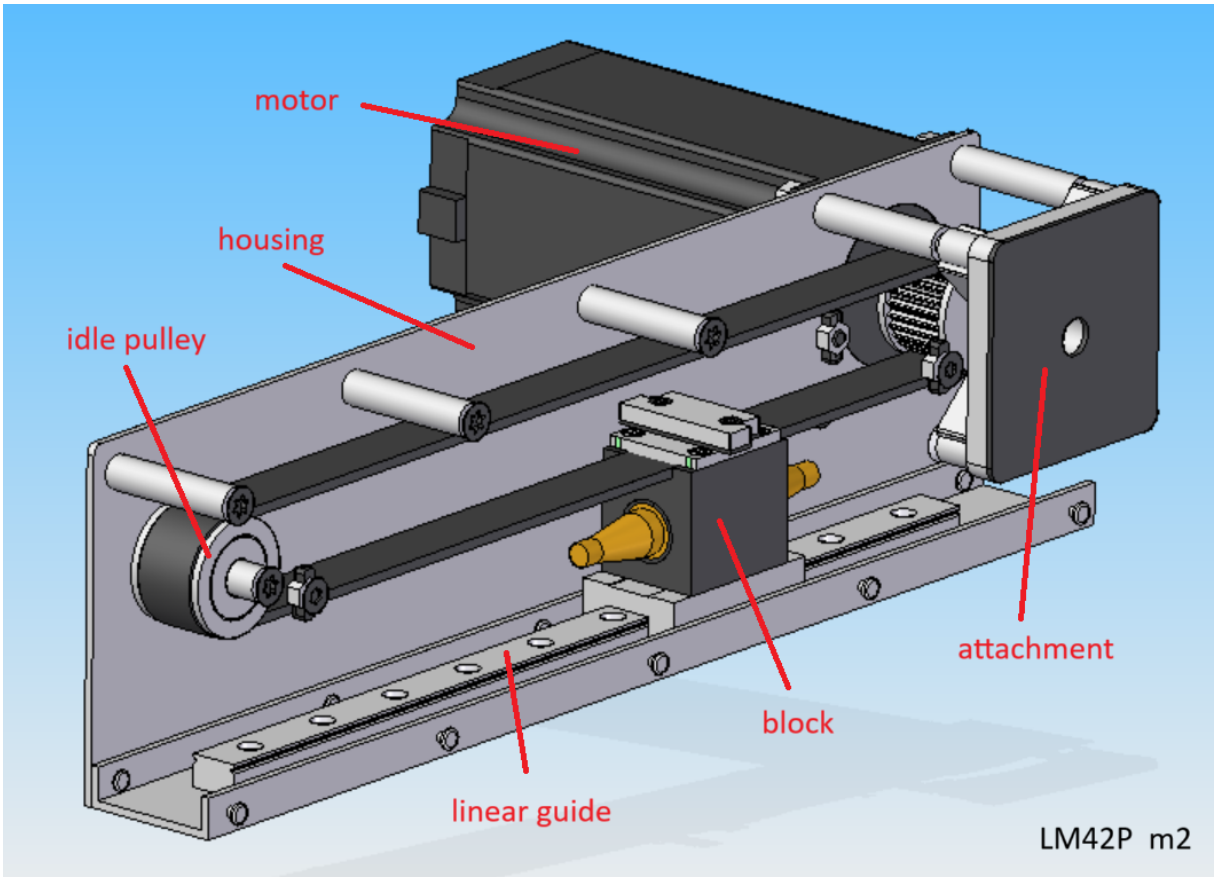
- **M1**
- **M2**

Before you begin building your machine, please take note of the following important information :

- For the 3D-printed parts, all files are located in the directory named `3d-print-files`, which is inside the parent directory named after the corresponding part.
- All part names are marked in **bold**.
- Apply threadlock to the screws.

Chapter 1

m2


motor
housing
idle pulley
attachment
block
linear guide
LM42P m2

1.1 housing

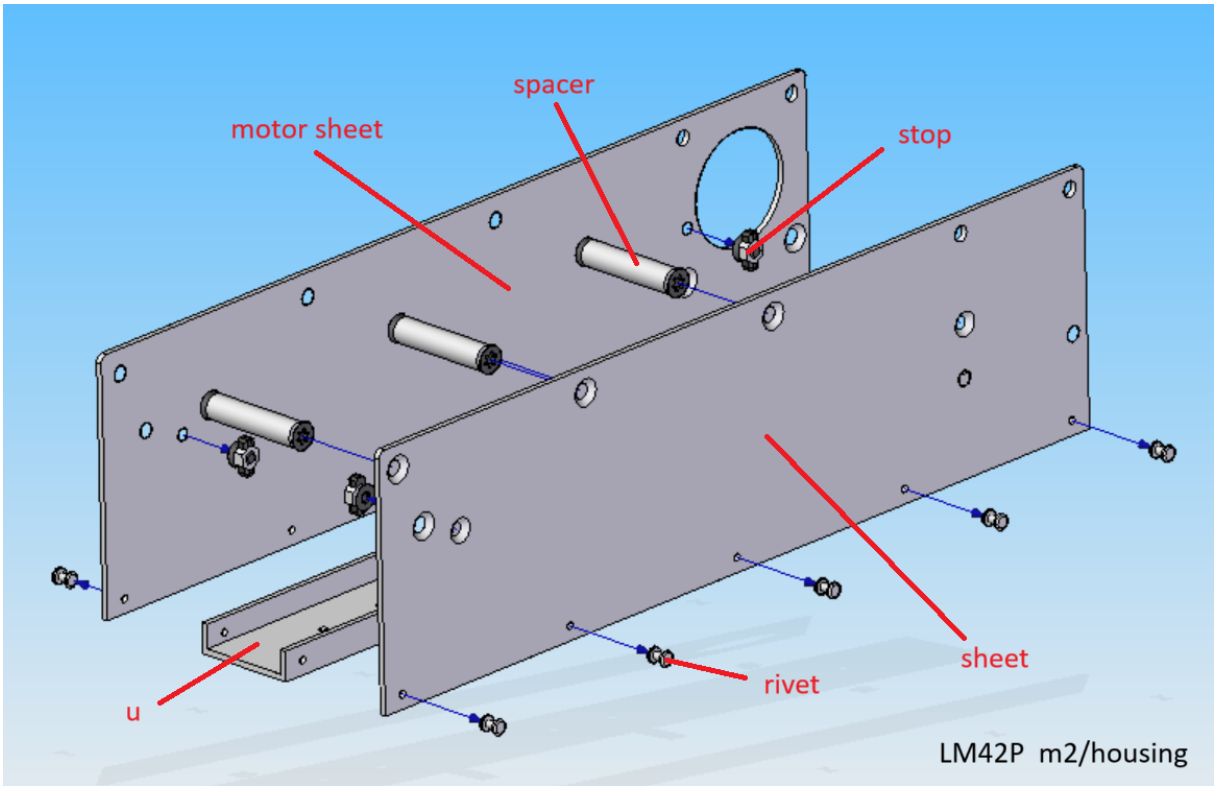


Figure 1.1: m2 housing parts

1.1.1 Parts list

Table 1.1: Parts list of housing

Qty	Part	Description	Material
1	u	10x35x250	aluminium
1	sheet	86x305x2	aluminium
1	motor sheet	86x305x2	aluminium
4	stop	13.7x33x4	aluminium
3	spacer	see section spacer	-
10	rivet	2.4 x 8 mm	aluminium

1.1.2 sheet

This section describes the manufacturing process for the part called **sheet**.

Drawing

See Figure 1.2, page 13.

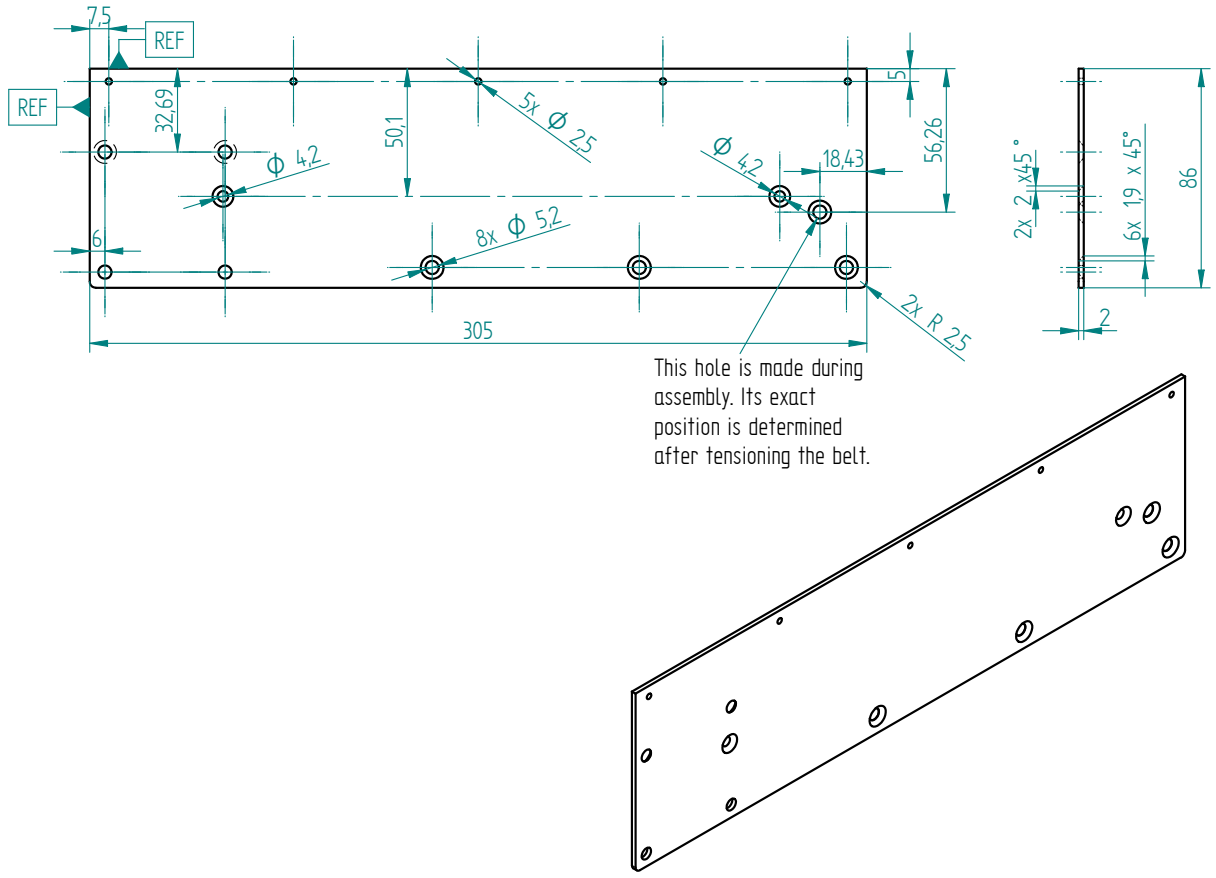


Figure 1.2: Drawing of the **sheet** part

Required Tools and Components

Below is the list of materials required to produce the part named **sheet**.

- 1x sheet dimensions : 86x305x2 material : aluminium ;
- 1x **steel rule** ;
- 1x **file** ;
- 1x **drillator** see section drillator 1.1.5, p. 20 ;
- 1x **drillator-m** see section drillator-m 1.1.6, p. 22 ;
- 4x **clamp** ;
- 2x **2.5 mm drill bit** ;
- 1x **4.2 mm drill bit** ;
- 1x **5.2 mm drill bit** ;
- 1x **chamfering tool** ;
- 1x **drill press**.

Manufacturing Instructions

1. use a **file** to remove all sharp edges ;
2. carefully determine which face requires protection before proceeding ;
3. align and clamp the **drillator-m**, using the top-left corner as a reference, this is important for proper alignment ;
4. center punch all holes using a **2.5 mm drill bit** ;
5. remove the **drillator-m** ;
6. using the same drill bit, drill the two holes positioned at the far-left edge, one at the uppermost and one at the lowermost position ;
7. using two **2.5 mm drill bits**, align and clamp the **drillator** ;
8. center punch all holes ;
9. remove the **drillator** ;
10. drill all holes ;
11. chamfer all holes (use a screw to check the chamfer depth) ;
12. use a **file** to create both R 2.5 mm radii ;
13. remove the protective film or masking.

1.1.3 motor-sheet

This section describes the manufacturing process for the part called **motor-sheet**.

Drawing

See Figure 1.3, page 15.

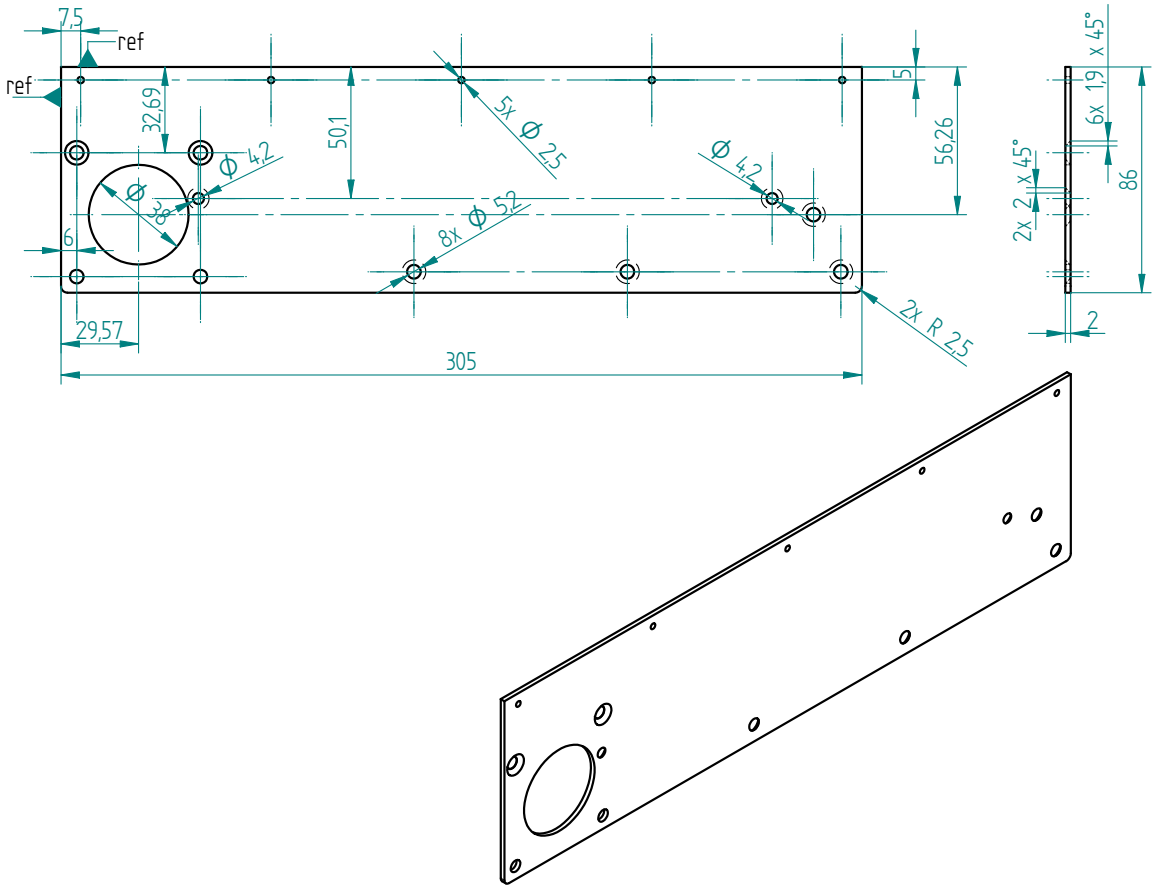


Figure 1.3: Drawing of the **motor-sheet** part

Required Tools and Components

Below is the list of materials required to produce the part named **motor-sheet**.

- 1x sheet dimensions : 86x305x2 material : aluminium ;
- 1x **flat/convex file** ;
- 1x **drillator** see section drillator 1.1.5, p. 20 ;
- 1x **drillator-m** see section drillator-m 1.1.6, p. 22 ;
- 1x **scribe** ;
- 4x **clamp** ;

- 2x **2.5 mm drill bit** ;
- 1x **4.2 mm drill bit** ;
- 1x **5.2 mm drill bit** ;
- 1x **jigsaw** ;
- 1x **chamfering tool** ;
- 1x **drill press**.

Manufacturing Instructions

1. use a **file** to remove all sharp edges ;
2. carefully determine which face requires protection before proceeding ;
3. align and clamp the **drillator-m**, using the top-left corner as a reference, this is important for proper alignment ;
4. using a **scriber**, mark the outline of the 38 mm diameter hole ;
5. center punch all holes using a **2.5 mm drill bit** ;
6. remove the **drillator-m** ;
7. using the same drill bit, drill the two holes positioned at the far-left edge, one at the uppermost and one at the lowermost position ;
8. using two **2.5 mm drill bits**, align and clamp the **drillator** ;
9. center punch all holes ;
10. remove the **drillator** ;
11. drill all holes ;
12. chamfer all holes (use a screw to check the chamfer depth) ;
13. use a **file** to create both R 2.5 mm radii ;
14. using a **jigsaw**, cut as close as possible to the 38 mm diameter outline ;
15. Using a **flat/convex file**, file the 38 mm hole until the motor fits through ;
16. remove the protective film or masking.

1.1.4 u

This section describes the manufacturing process for the part called **u**.

Drawing

See Figure 1.4, page 17.

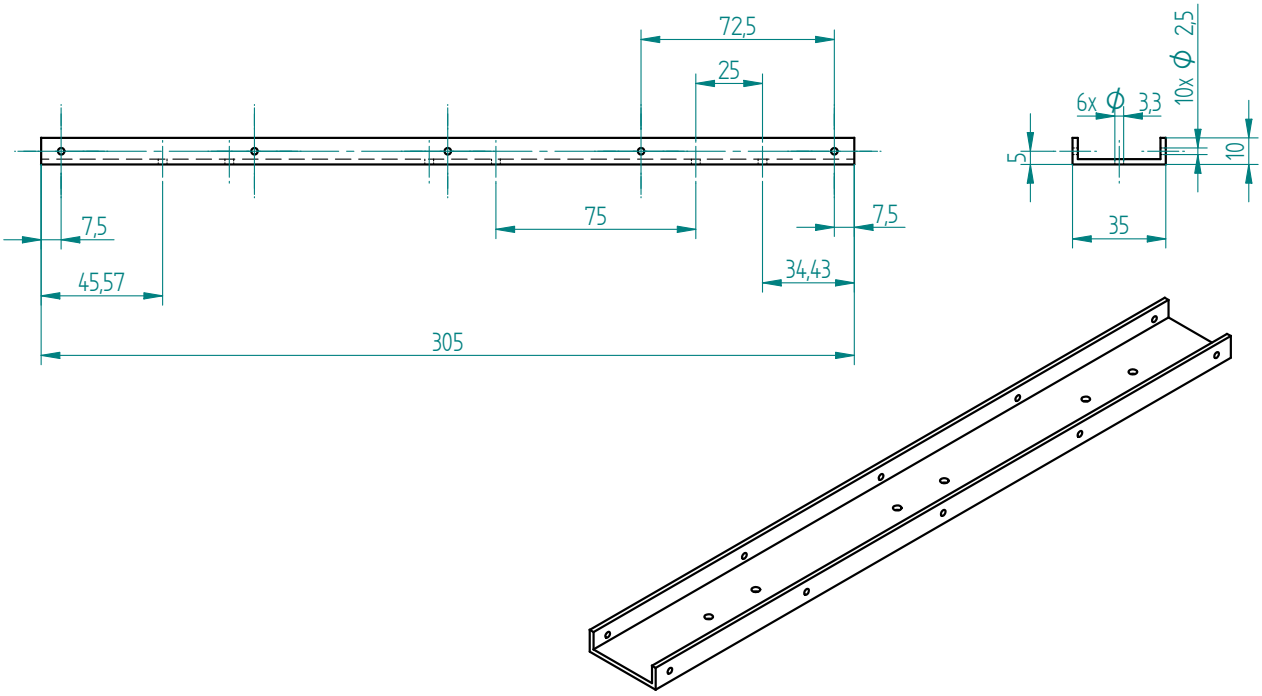


Figure 1.4: Drawing of the **u** part

Required Tools and Components

Below is the list of materials required to produce the part named **u**.

- 1x **square tube** dimension : 35x35x2x305 material : aluminium ;
- 1x **gauge** minimum length: 305 mm ;
- 1x **try square** ;
- 1x **steel rule** ;
- 1x **scriber** ;
- 1x **hand saw** ;
- 1x **perpendicaltor** ;
- 1x **file** ;
- 1x **rail** (see section **linear-guide** 1.2, p. 26) ;
- 2x **clamp** ;
- 1x **3.5 mm drill bit** ;
- 1x **3.3 mm drill bit** ;
- 1x **2.5 mm drill bit** ;
- 1x **chamfering tool** ;
- 1x **drill press**.

Manufacturing Instructions

1. scribe a line with a **scriber**, leaving approximately 0.3 mm of extra material beyond the final total length ;
2. cut the **square tube** to length using a **handsaw** and a **try square** ;
3. use the **perpendiculator** to ensure both ends are square ;
4. scribe two lines using the **scriber**, each about 0.3 mm from the edge of the squared **square tube** ;
5. cut the **square tube** along the scribed lines using the **handsaw** ;
6. use a **file** to clean the cuts and chamfer the edges ;
7. clamp the **rail** in the correct position using a **gauge** (make sure it's centered), see Figure 1.5, page 19 ;

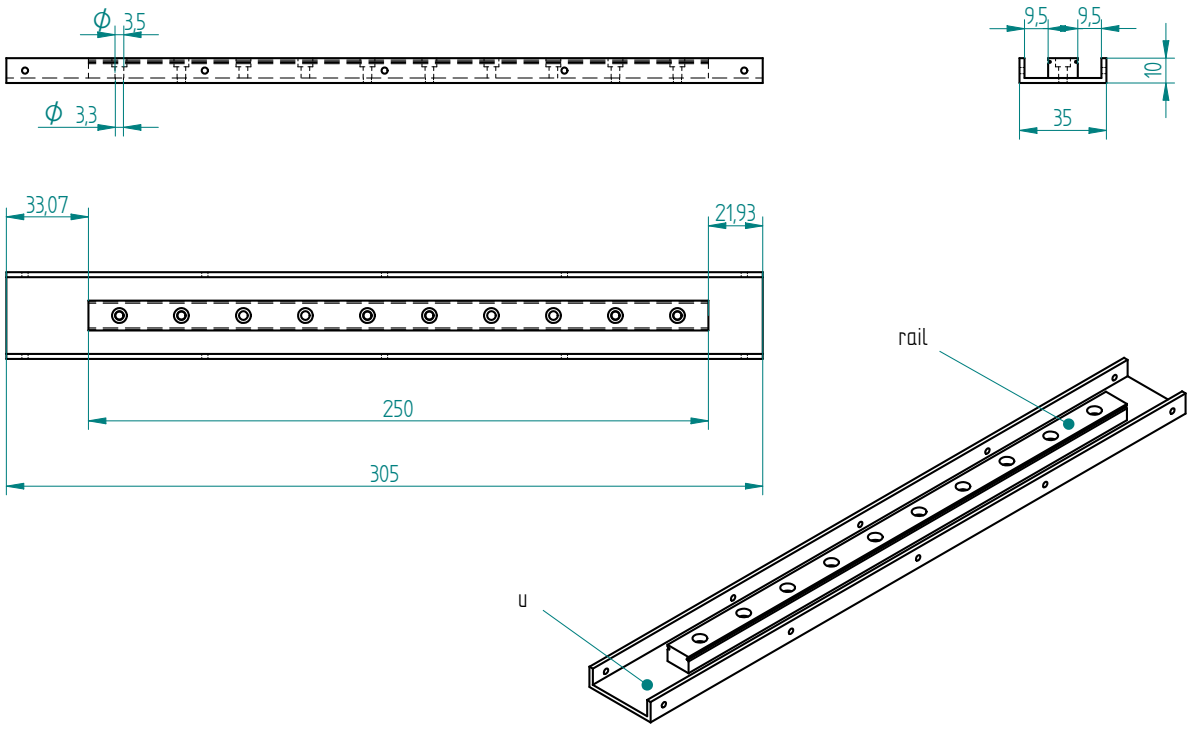


Figure 1.5: Center punch the 3.3 mm hole through the **rail** using a **3.5 mm drill bit**

8. mark the positions of the six 3.3 mm holes using a **3.5 mm drill bit** to center punch ;
9. drill the six holes using a **3.3 mm drill bit** (do not drill the 2.5 mm holes yet—those will be drilled with the sheets) ;
10. chamfer the six holes using a **chamfering tool** ;
11. clamp the **sheet** in place ;
12. center punch the five holes using a **2.5 mm drill bit** ;
13. clamp the **motor sheet** ;
14. center punch the five holes using a **2.5 mm drill bit** ;
15. drill all ten holes using a **2.5 mm drill bit** ;
16. chamfer the six holes using a **chamfering tool**.

1.1.5 drillator

This section describes the manufacturing process for the part called **drillator**.

Remark : If your 3D printer has a large enough build volume, you can print the **drillator** and **drillator-m** in one piece, which improves alignment accuracy.

Drawing

See Figure 1.6, page 21.

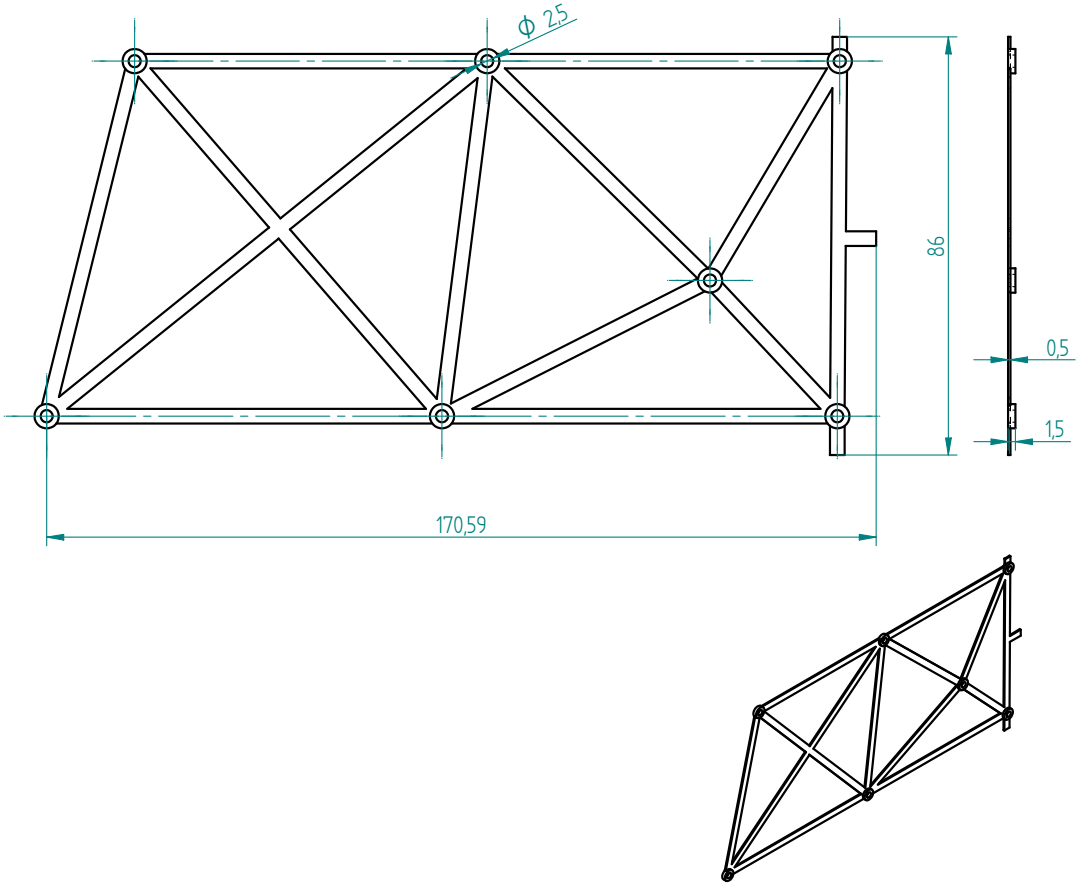


Figure 1.6: Drawing of the **drillator** part

Required Tools and Components

Below is the list of materials required to produce the part named **drillator**.

- 1x **3d printer** ;
- 1x **PLA** ;
- 1x **file** ;
- 1x **drill** ;
- 1x **2.5 mm drill bit**.

Manufacturing Instructions

1. 3D print the part using the files located in the `3d-print-files` directory ;
2. chamfer the edges using a **file** ;
3. drill the 2.5 mm holes using a **2.5 mm drill bit** and a **drill**.

1.1.6 drillator-m

Remark : If your 3D printer has a large enough build volume, you can print the **drillator** and **drillator-m** in one piece, which improves alignment accuracy.

Drawing

See Figure 1.7, page 23.

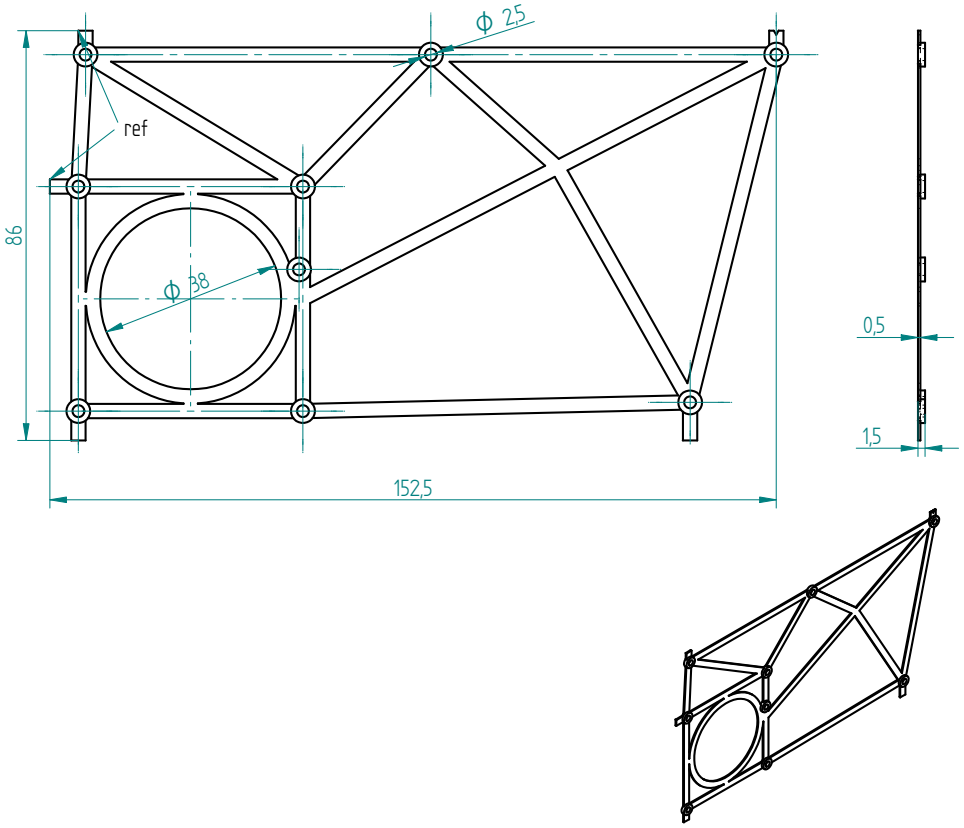


Figure 1.7: Drawing of the **drillator-m**

Required Tools and Components

Below is the list of materials required to produce the part named **drillator**.

- 1x **3d printer** ;
- 1x **PLA** ;
- 1x **file** ;
- 1x **drill** ;
- 1x **2.5 mm drill bit**.

Manufacturing Instructions

1. 3D print the part using the files located in the `3d-print-files` directory ;
2. chamfer the edges using a **file** ;
3. drill the 2.5 mm holes using a **2.5 mm drill bit** and a **drill**.

1.1.7 stop

Drawing

See Figure 1.8, page 24.

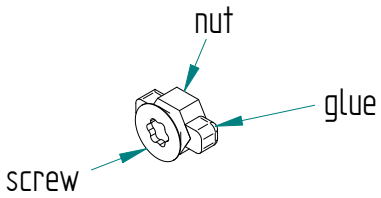


Figure 1.8: Drawing of the **stop**

Parts list

Table 1.2: Parts list of housing/stop

quantity	name	specification	material
`4x1=4`	**screw**	M4 × 6 mm Torx flat head screw	stainless steel
`4x1=4`	**nut**	standard M4 hex nut	stainless steel
`-`	**glue**	black	Poliflex 444

1.1.8 spacer

Drawing

See Figure 1.9, page 25.

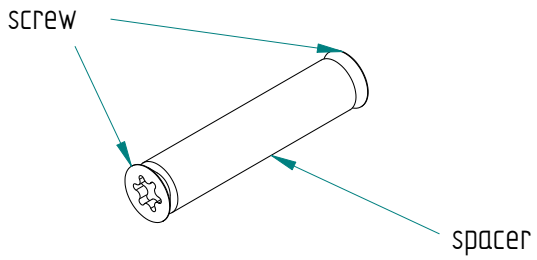


Figure 1.9: Drawing of the **spacer**

Parts list

Table 1.3: Parts list of housing/spacer

Qty	Part	Description	Material
3x2=6	**screw**	M5 × 12 mm Torx flat head screw	stainless steel
3x1=3	**spacer**	M5 x 8 x 35 mm	aluminium

1.2 linear guide

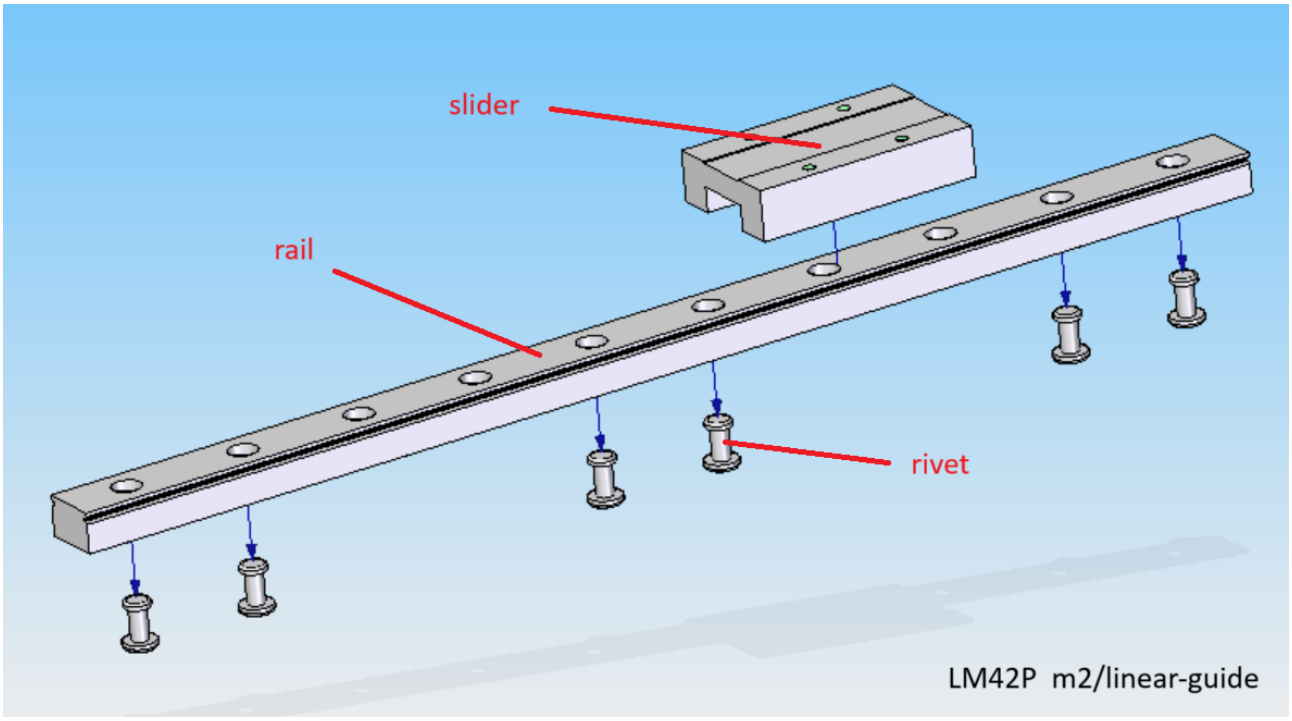


Figure 1.10: m2 linear guide parts

1.2.1 Parts list

Table 1.4: Parts list of **linear guide**

Qty	Part	Description	Material
1	rail	MGN12H, length: 250 mm	-
1	slider	MGN12H, 27 x 45.4 mm	-
6	rivet	3.2 x 10 mm	aluminium

1.2.2 Drawing

See Figure 1.11, page 27.

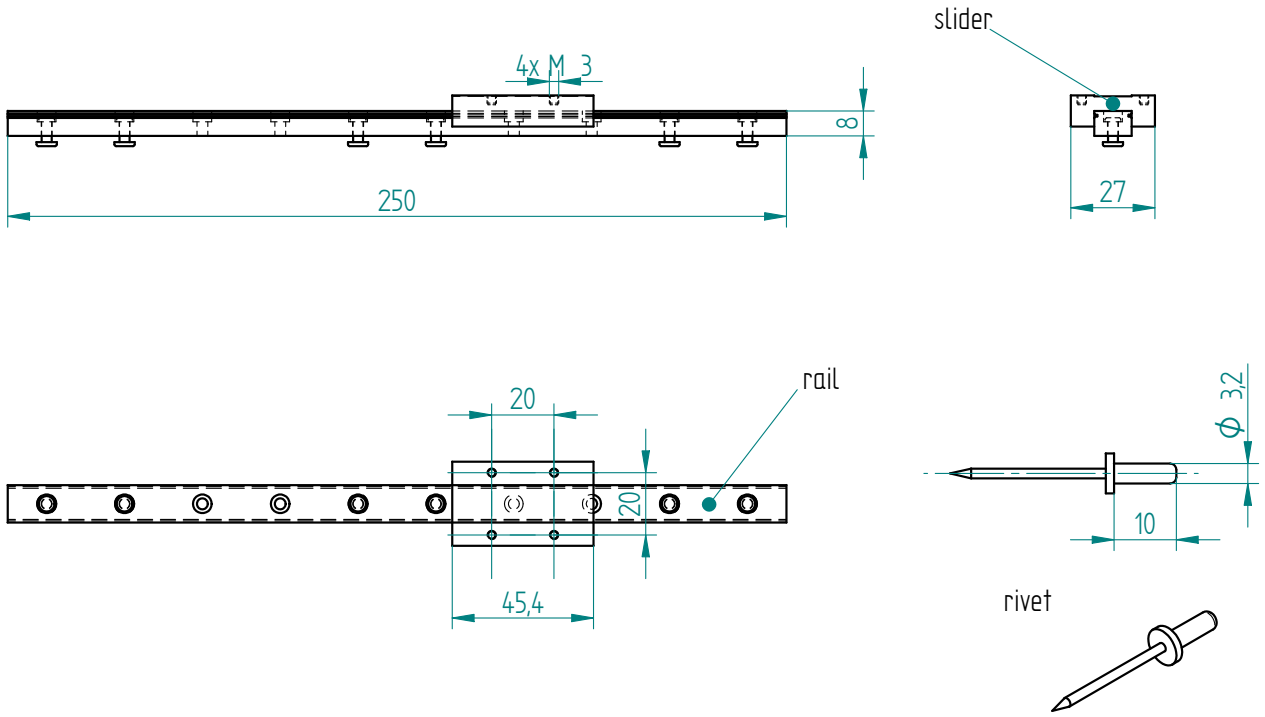


Figure 1.11: Drawing of the linear guide parts

1.3 block

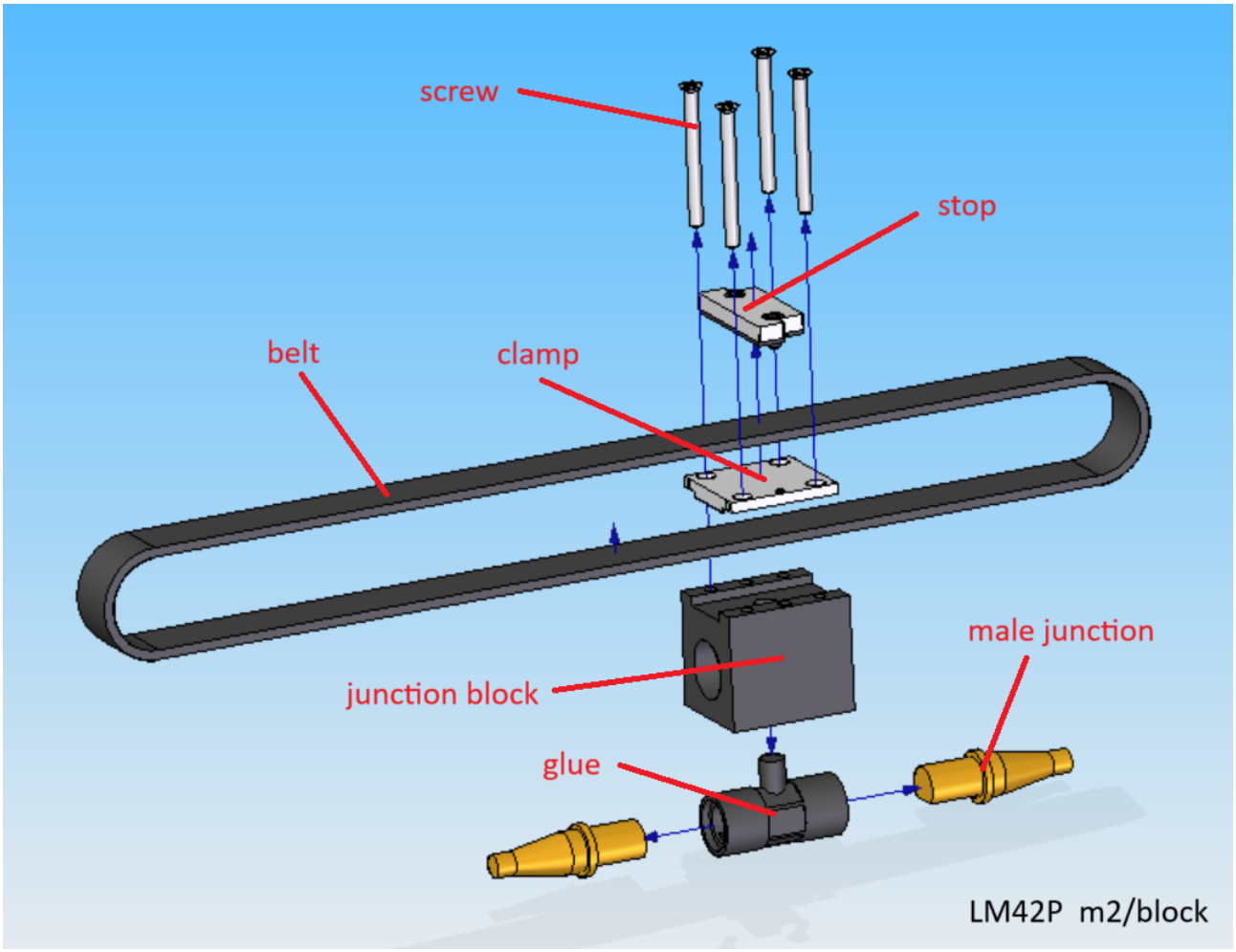


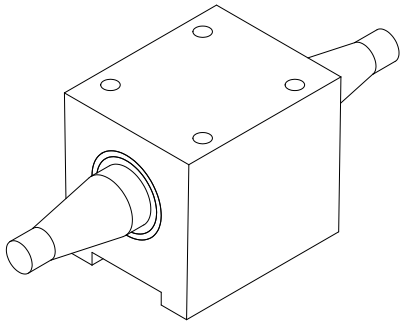
Figure 1.12: m2 block parts

1.3.1 Parts list

Table 1.5: Parts list of **block**

Qty	Part	Description	Material
1	junction block	3D printed	nylon
1	glue	casted	epoxy
2	male junction	google : `pool cue junction`	brass
1	belt	HTD 3	-
1	clamp	HTD 3	aluminium
1	stop	subassemblie (see section)	see section **stop**
4	screw	M3 × 36 mm flat head screw	stainless steel

1.3.2 junction block



Drawing

See Figure 1.13, page 30.

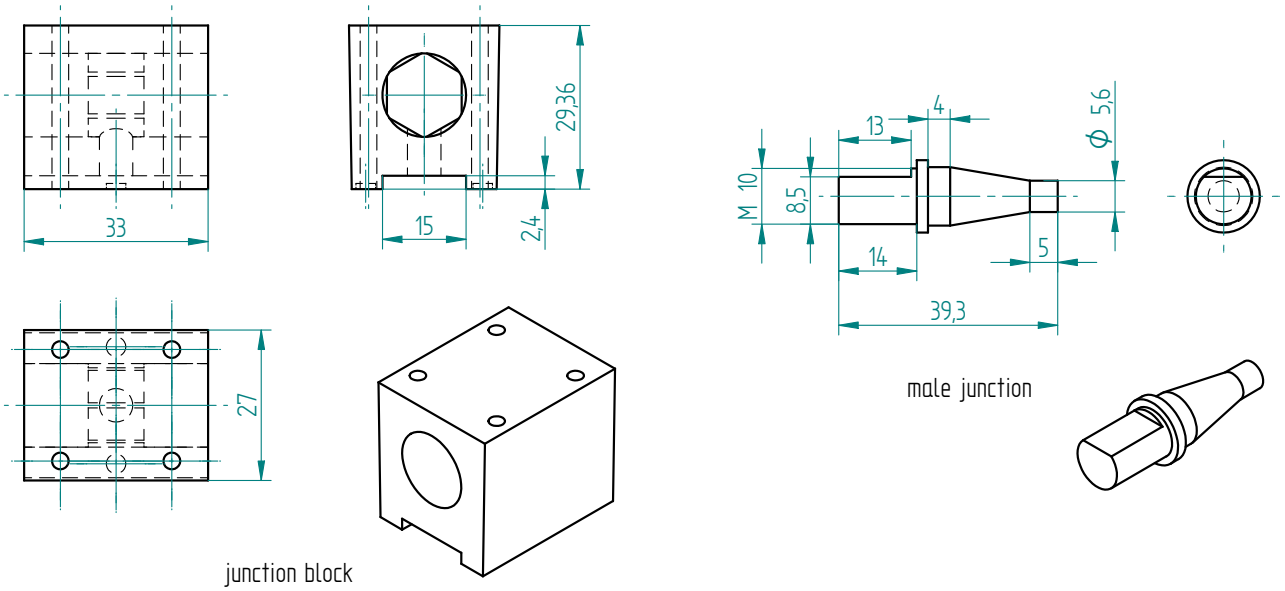


Figure 1.13: Drawing of the junction block parts

Required Tools and Components

- 1x 3D printer ;
- 1x nylon filament ;
- 1x STL file ;
- 2x male junction ;
- 1x file ;
- 1x gauge ;
- 4x screw (M3, length=36mm) ;
- 1x alignator ;
- 1x glue ;
- 2x rods ;
- 2x elastic ;
- 1x hot glue.

Manufacturing Instructions

1. 3D print the **junction block** using the STL file and nylon filament.
2. File a flat surface of 8.5 x 13 mm on the threaded M10 part (on both **junction block**.
3. Mount the **junction block** on the **alignator** (**slider**) with the **spacer** and the four **screw-3x**.
4. Insert a **male junction** on each end of the **rod**.
5. Place the **slider** on the **rail** and both **rods** on the **v**.
6. Attach using two **elastic** bands.
7. Press the **rods** against the **junction block**.
8. Fix them in place with **hot glue**. See Figure 1.14, page 32 and Figure 1.15, page 32.

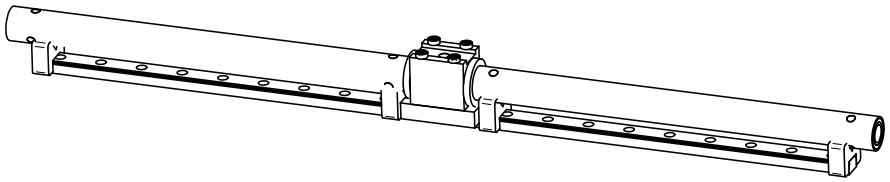


Figure 1.14: male junction aligning

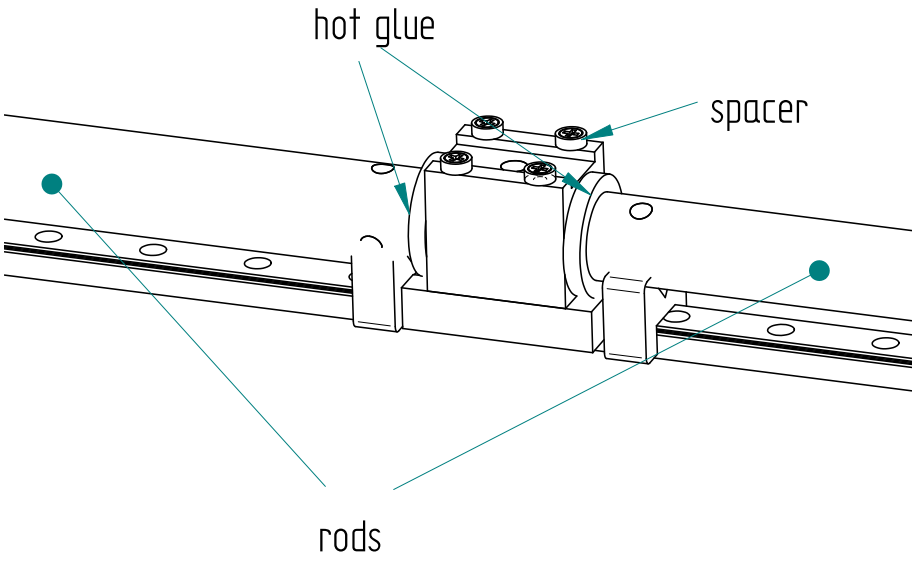


Figure 1.15: male junction aligning zoomed

9. Test the seal by blowing into the hole of the **junction block**.
10. Prepare the **glue**[1]:
    (a) Quantity **hardener**: 2 g ;
    (b) Quantity **resin**: 5 g ;
    (c) Quantity **graphite powder**: 1.5 g.
11. Pour the mixture into the **junction block**.
12. Cure for 24 hours at 20°C or 4 hours at 40°C.
13. Remove the **hot glue**.
14. Remove the four **screw-3x** and the **spacer**.

[1] Adjust the quantity of **resin** and **hardener** according to the type of glue used.

1.3.3 belt

Drawing

See Figure 1.16, page 34.

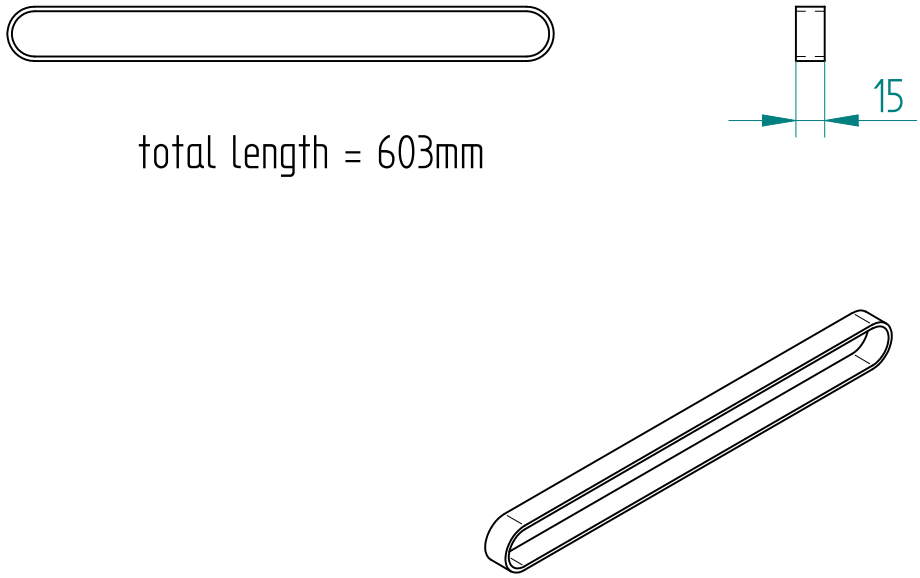


Figure 1.16: Drawing of the belt

Required Tools and Components

- 1x roll of belt standard HTD-5M ;
- 1x double meter ;
- 1x scissors.

Manufacturing Instructions

1. Cut a **belt** with a length of 603 mm .

1.3.4 clamp

Drawing

See Figure 1.17, page 35.

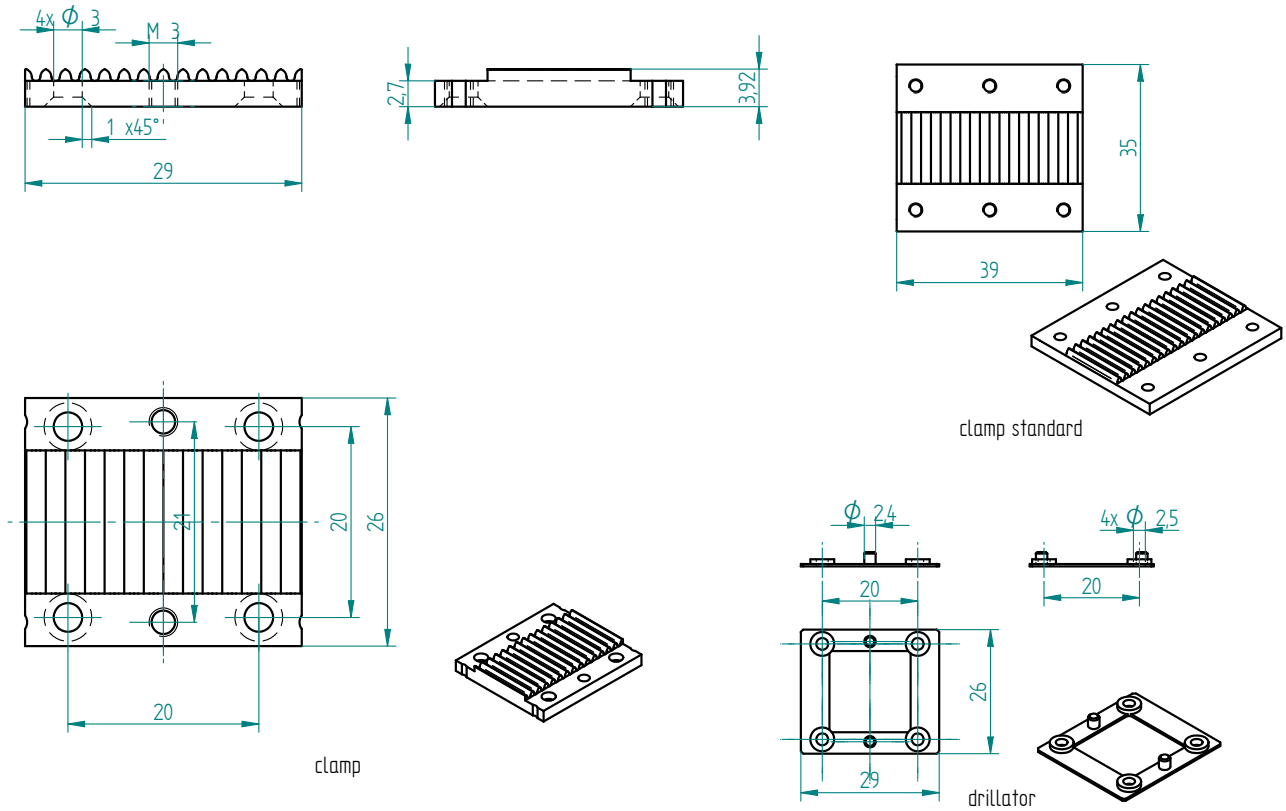


Figure 1.17: Drawing of the clamp

Required Tools and Components

- 1x clamp standard ;
- 1x 3D printer ;
- 1x PLA filament ;
- 1x STL file ;
- 1x drillator ;
- 2x clamp ;
- 1x scriber ;
- 1x file ;

- 1x 2.5 mm drill bit ;
- 1x 3 mm drill bit ;
- 1x chamfer mill ;
- 1x driller ;
- 1x drill press ;
- 1x gauge.

Manufacturing Instructions

1. 3D print the **drillator** using the provided STL file and PLA filament.
2. Clamp the **drillator** onto the **clamp standard**.
3. Scribe the outer dimensions.
4. Center punch the four holes.
5. Mill or cut the shape to size using a **handsaw**, according to the **Drawing** section.
6. Chamfer all sharp edges.
7. Drill the four holes using a 3 mm drill bit.
8. Chamfer all four holes: $1 \times 45°$.

1.3.5 screw

These screws are used to assemble the **stop**, **belt**, **clamp**, and **junction block** onto the **slider**. Initially, the exact screw length cannot be determined. The objective is to ensure that the threaded portion engages as much as possible with the **slider**, so the **screw** holds securely.

Drawing

See Figure 1.18, page 37.

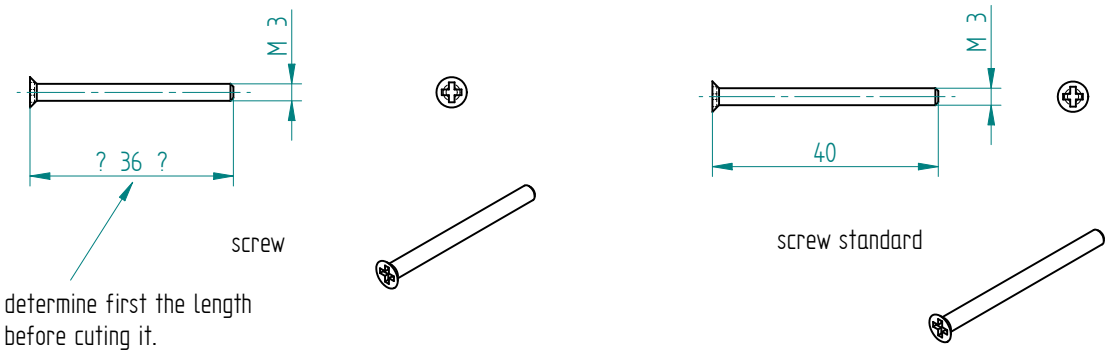


Figure 1.18: Drawing of the screw

Required Tools and Components

- 4x screw standard (M3, length = 40 mm) ;
- 1x **junction block** ;
- 1x **belt** ;
- 1x **clamp** ;
- 1x depth gauge ;
- 1x handsaw ;
- 1x file ;

- 1x gauge ;
- 1x Phillips screwdriver ;
- 1x bench vise.

Manufacturing Instructions

1. Place the **belt** between the **clamp** and the **junction block**.
2. Use a **screw-40** to loosely secure the **belt** and the **junction block** onto the **slider**.
   Tighten the screw until it reaches the end of the internal thread in the slider.
   *Warning: It's normal if the **junction block** is not fully tightened—this screw is slightly too long.*
3. Using a **depth gauge** or ruler, measure how much of the **screw** needs to be cut off.
4. Cut the **screw standard** to the correct length using a **handsaw**.
   *Tip: Use a **bench vise** to hold the screw steady while cutting.*
   *Deburr the end with a **file** for a clean finish.*
5. Based on the first test, the ideal screw length is approximately **36 mm**.

1.3.6 stop

Drawing

See Figure 1.19, page 39.

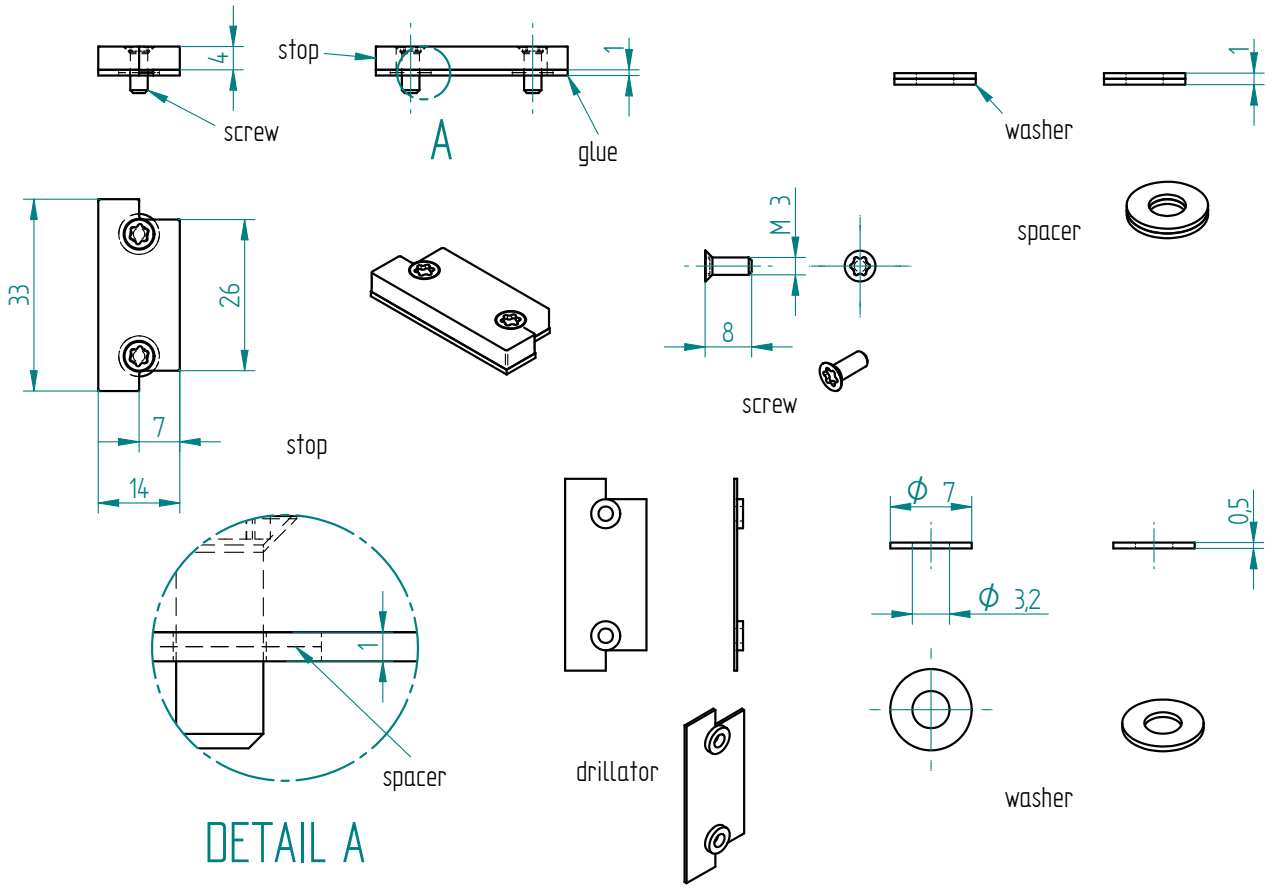


Figure 1.19: Drawing of the stop parts

Parts list

Table 1.6: Parts list of **block/stop**

quantity	name	specification	material
1	stop	14 x 4 x 33	aluminium
4	washer (2 spacer)	3.2 x 7 x 0.5	stainless steel
2	screw	M3 × 8 mm Torx flat head screw	stainless steel
1	glue	-	Poliflex 444

Required Tools and Components

- 1x 14 x 33 aluminium sheet thickness 4 mm ;
- 2x clamps ;

- 1x scriber ;
- 1x drillator ;
- 1x mill ;
- 1x file ;
- 1x 2.5 mm drill bit ;
- 1x 3 mm drill bit ;
- 1x chamfer mill ;
- 1x driller ;
- 1x drill press.

Manufacturing Instructions

1. Mill or file the **stop** (using the tool **drillator**) according to the dimensions shown in the **Drawing** ;
2. Using the shaped tool **drillator**, drill both holes ;
3. Drill and chamfer the two 3 mm holes .

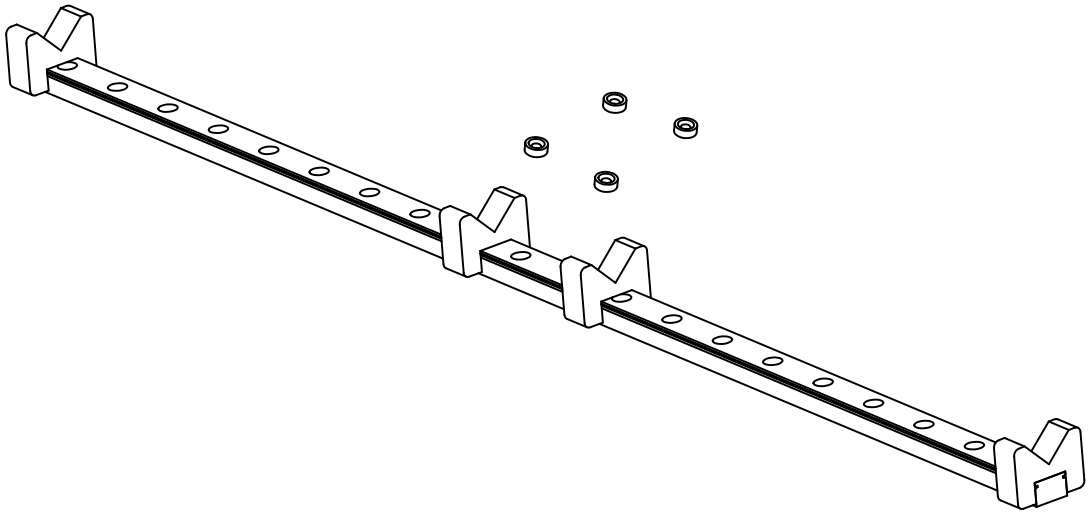
1.3.7 Assembling Instructions

Required Tools and Components

- 1x glue pistol ;
- 1x glue ;
- 1x Torx screwdriver ;
- 4x washer (2 spacer) ;
- 1x threadlocker.

1. Apply **threadlocker** to the four **screw**.
2. Secure the **belt** using the **clamp** and the four **screw-3x** onto the **slider**.
3. Apply **mastic glue** to the **stop**.
4. Ensure the two **spacers** are in place.
5. Apply **threadlocker** to the screws.
6. Fasten the **stop** onto the **clamp**.
7. Allow to cure for 24 hours.

1.3.8 alignator



The purpose of this tool is to align the **male junction** inside the **junction-bloc** during glueing. The **male junction** is screwed in the **rod** the latter is placed on the **v**.

Assemblies In the figure 1.20, page 42 we can see the **alignator** fully assembled with it's components.

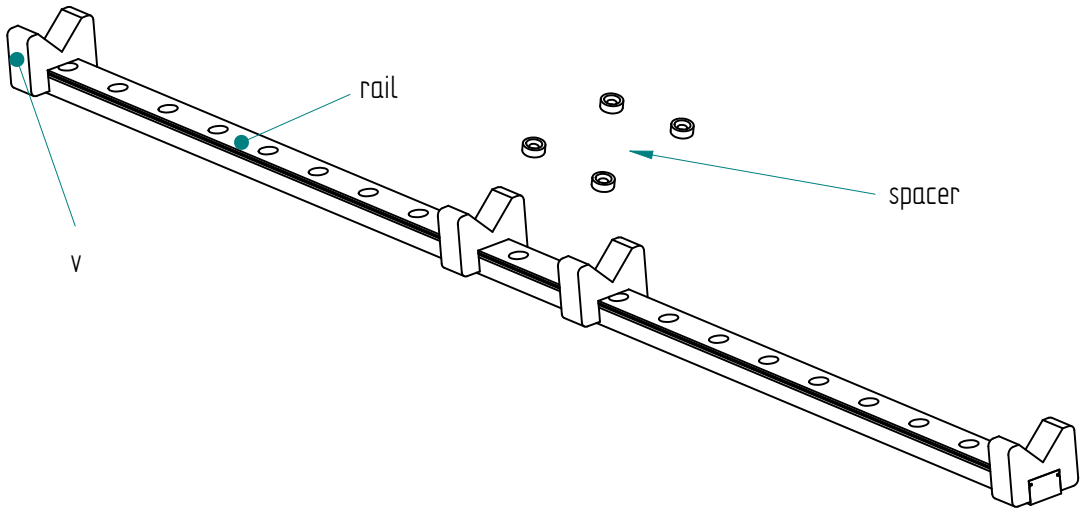


Figure 1.20: **alignator** assembled

Roadmap This paragraph shows how to build the **alignator**.
It's not necessary to follow straight all these points one after another, but I think it's the most logical to do it in these steps I thinks :

1. prepare all stuff in the **Parts list** with the tools showed in the **Tools list** ;
2. assemble the **alignator**.

Parts list In this pargraph we can find the whole list of parts that the perpendiculator needs, like :

- 1 x **rail** ;
- 4 x **spacer** ;
- 1 x PLA (3d printing).

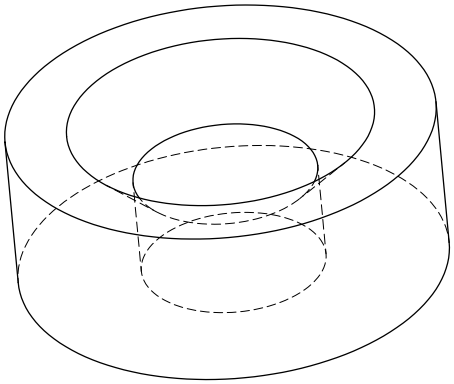
Tools list In this paragraph we can find the list of tools that we need to build the **alignator**, like :

- 3d printer ;
- torks screwdriver.

Shaped-parts In this paragraph we can find the shaped parts that the **alignator** requires, like :

- **spacer** ;
- **v**.

spacer



This paragraph show how to build the **spacer**.

Drawing The figure 1.21, page 44, show the drawing of the **spacer**.

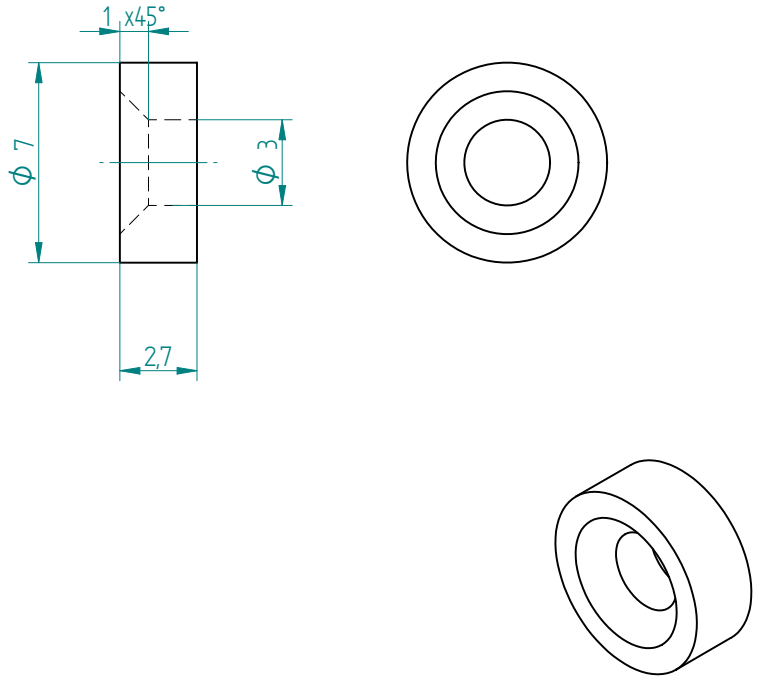


Figure 1.21: **spacer** drawing for **alignator**

Quantity 4 ;

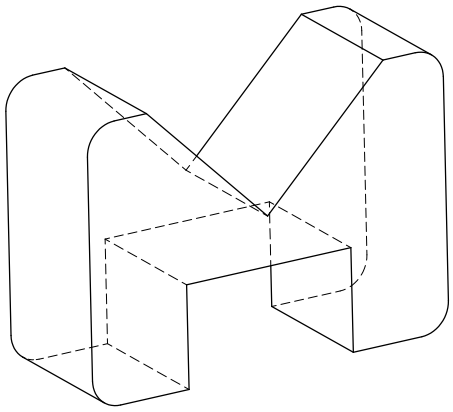
Material PLA 3d printed.

Roadmap

1. copy the file named **UM2_spacer.gcode** from the **3d-print-files** folder to the 3d printer ;

2. print the 4 **spacer** with a 3d printer.

v



This paragraph show how to build the **v**.

Drawing The figure 1.22, page 45, show the drawing of the **spacer**.

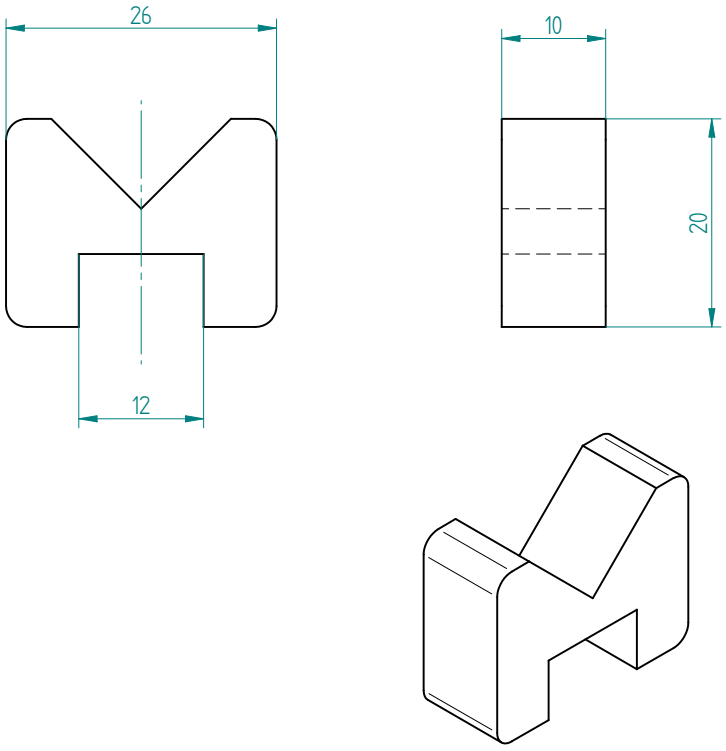


Figure 1.22: **v** drawing for **alignator**

Quantity 4 ;

Material PLA 3d printed.

Roadmap

1. copy the file named **UM2_v.gcode** from the **3d-print-files** folder to the 3d printer ;
2. print the 4 **v** with a 3d printer.

1.4 motor

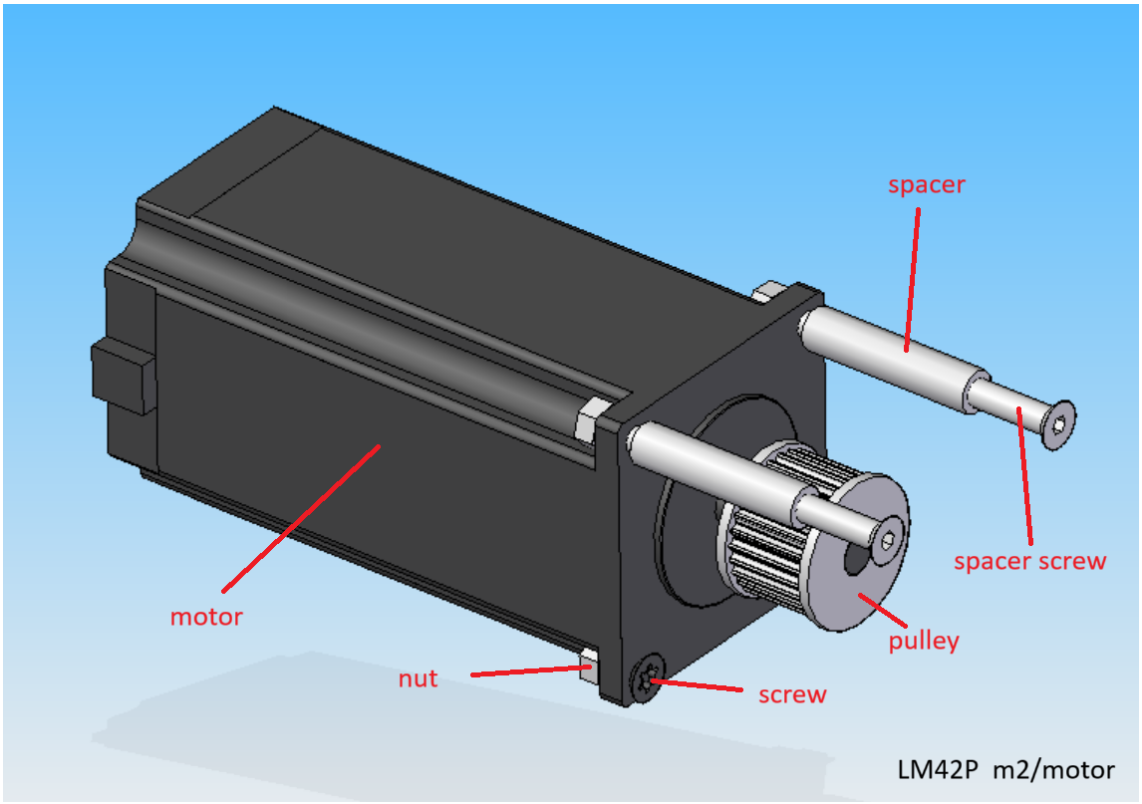


Figure 1.23: m2 motor parts

1.4.1 Parts list

Table 1.7: Parts list of **motor**

Qty	Part	Description	Material
1	**motor**	Nema 23 4.2A 3N.m 112mm	with cable
1	**pulley**	HTD M3 28T 16/8	aluminium
2	**spacer**	M5 x 8 x 35 mm	aluminium
2	**spacer screw**	M5 × 65 mm Torx flat head screw	stainless steel
2	**screw**	M5 × 12 mm Torx flat head screw	stainless steel
4	**nut**	M5	stainless steel

1.4.2 Drawing

See Figure 1.24, page 48.

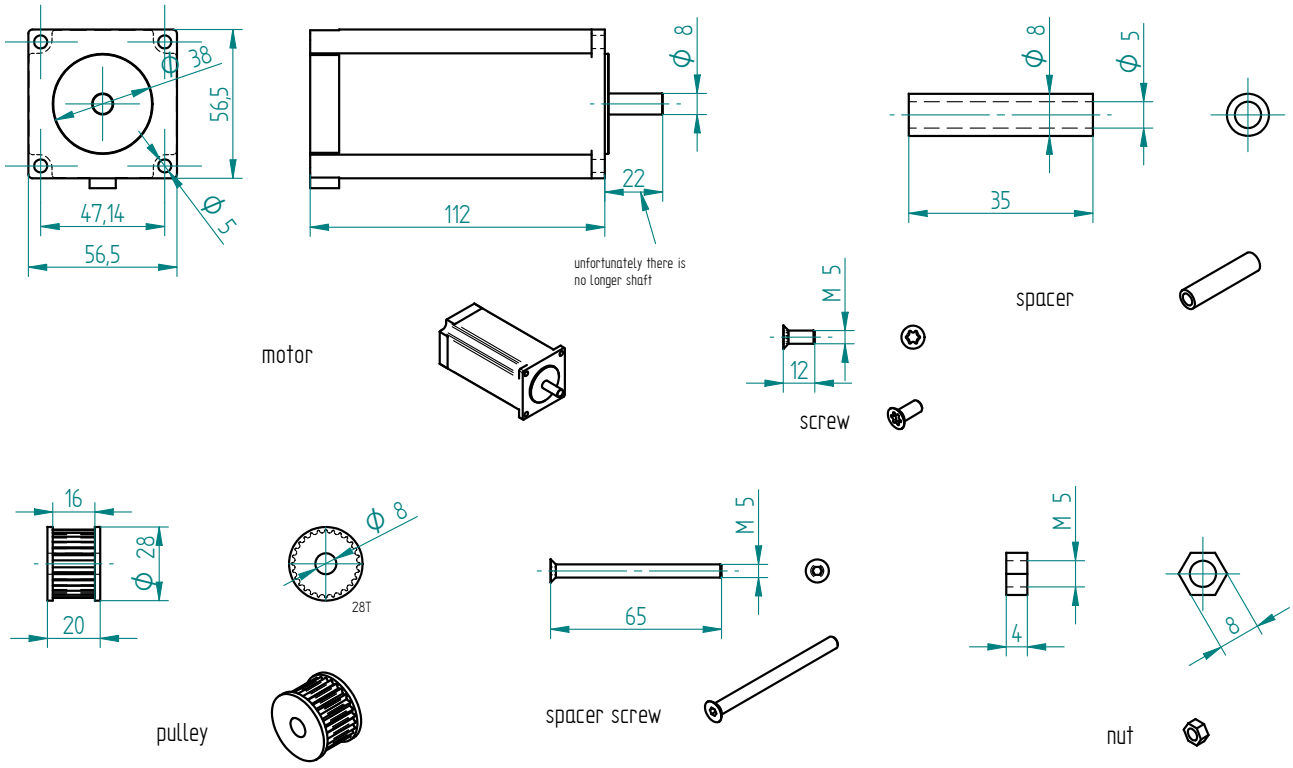


Figure 1.24: Drawing of the motor parts

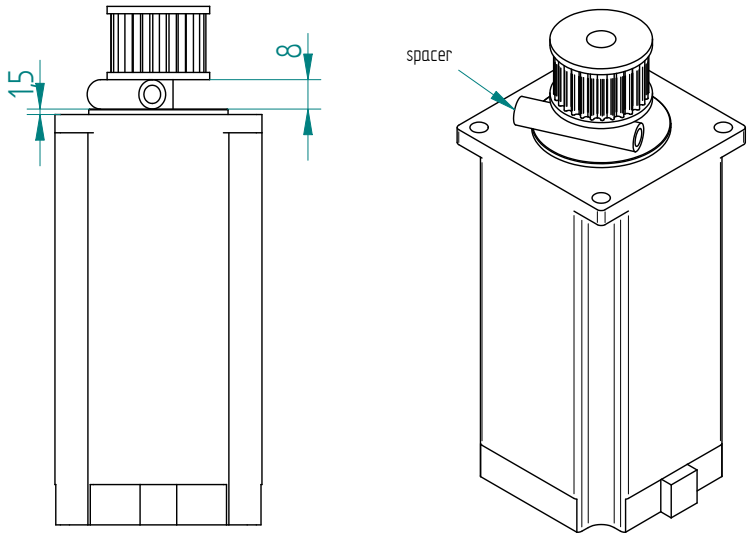


Figure 1.25: Position of the pulley on the motor shaft

1.4.3 Assembling Instructions

Required Tools and Components

- 1x **motor** ;
- 1x **pulley** ;
- 1x **spacer** ;
- 1x adjustable reamer, diameter 8 mm ;
- 1x sandpaper ;
- 1x acetone.
- 1x shaft glue (Loctite 238) ;

1. Test the **pulley** on the **motor** shaft.
   There should be a *slight gap* between them (for the shaft glue).
2. If there is no gap :
   - Use an adjustable reamer (diameter 8 mm) to carefully enlarge the hole in the **pulley** until the **pulley** fits with a slight gap.
3. Clean the shaft and the **pulley** with acetone.
4. Apply shaft glue to the shaft.
5. Press the **pulley** onto the **spacer**, using a **spacer** to ensure correct positioning (See Figure 1.25, page 49.
6. Let it cure for 4 hours.

1.5 idle pulley

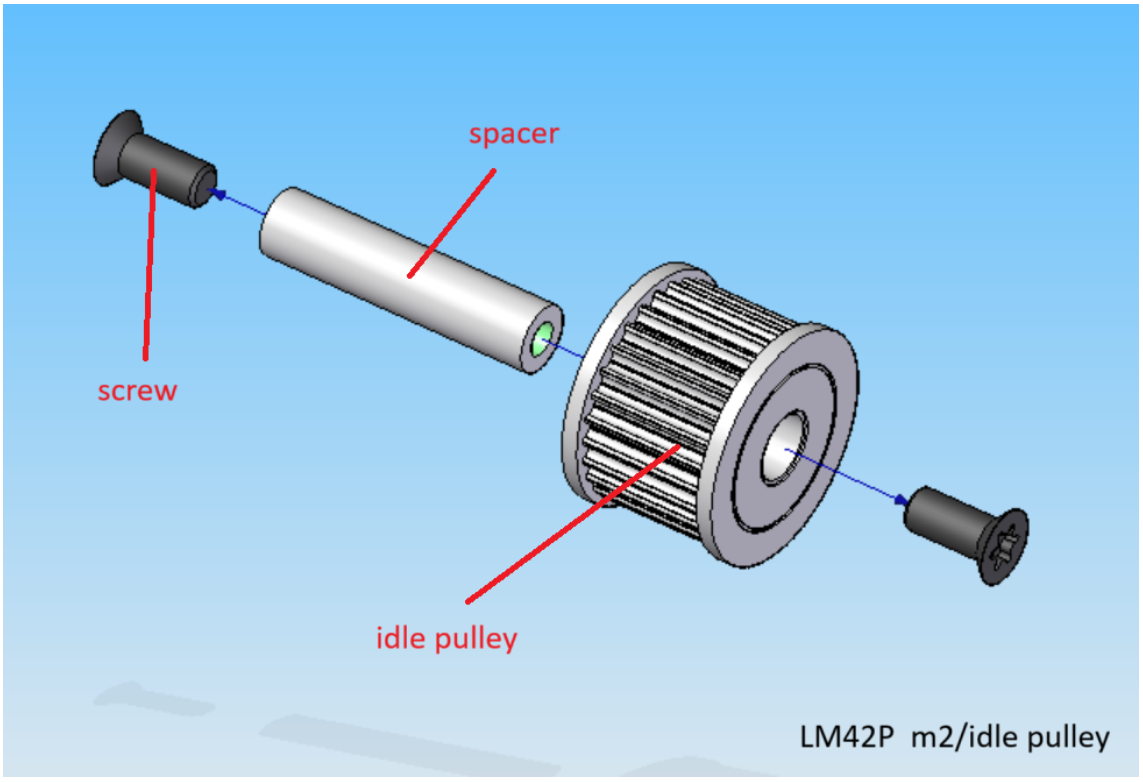


Figure 1.26: m2 idle pulley parts

1.5.1 Parts list

Table 1.8: Parts list of **idle pulley**

Qty	Part	Description	Material
1	**idle pulley**	HTD3 28T / 8	Aluminium
2	**screw**	M5 × 12 mm Torx flat head screw	stainless steel
1	**spacer**	M5 x 8 x 35 mm	Aluminium

1.5.2 Drawing

See Figure 1.27, page 51.

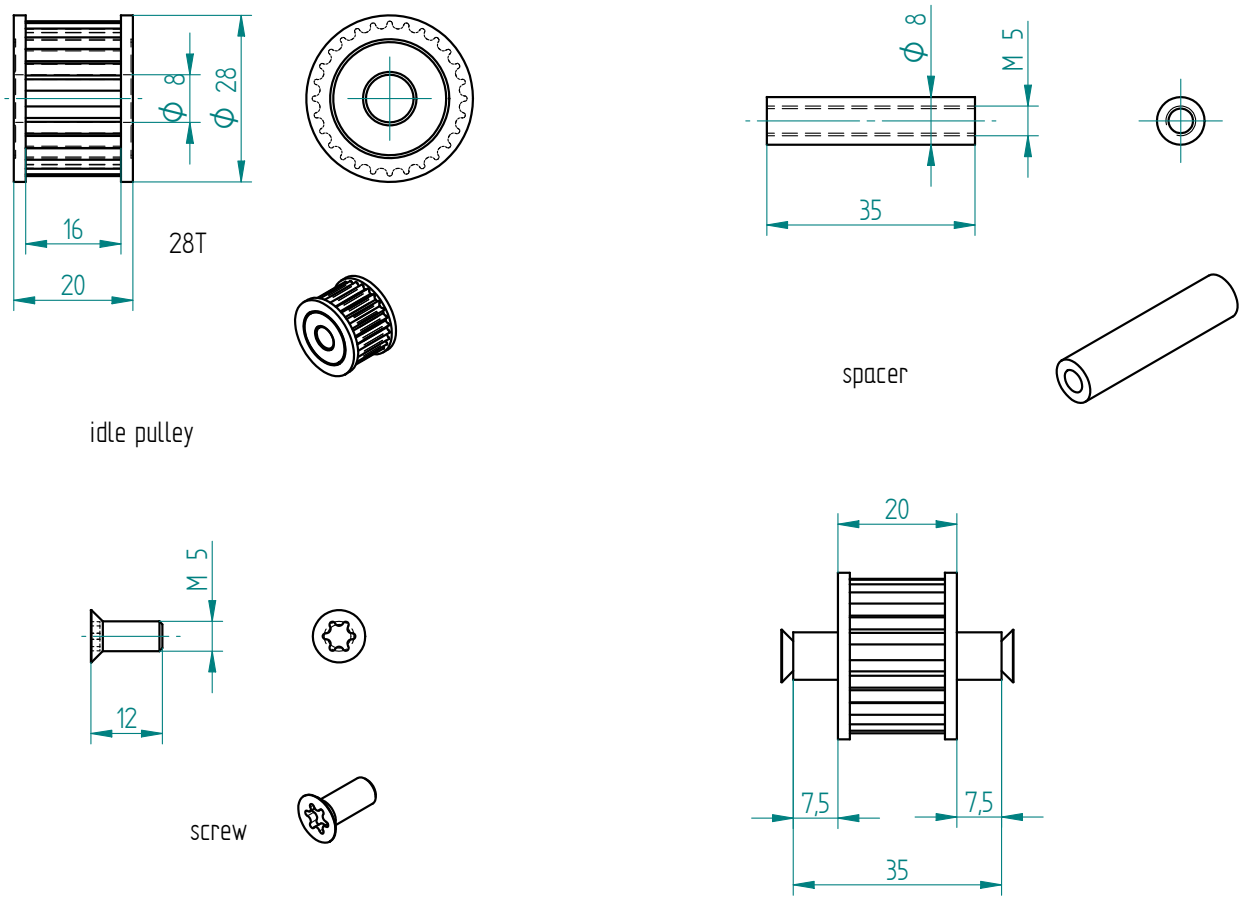


Figure 1.27: Drawing of the idle pulley parts

1.5.3 Assembling Instructions

Required Tools and Components

- 1x **idle pulley** ;
- 1x **spacer** ;
- 1x depth gauge ;
- 1x shaft glue (Loctite 238) ;
- 1x sandpaper ;
- 1x driller ;
- 1x M5 threader shaft ;
- 1x acetone.

1. Test the **idle pulley** on the **spacer**. There should be a *slight gap* between them (for the shaft glue).
2. If there is no gap :
    - Insert the threaded shaft into the **spacer** and mount it in a drill.
    - Use **sandpaper** to carefully reduce the outer diameter of the **spacer** until the **idle pulley** fits with a slight gap.
3. Clean the **spacer** and the **idle pulley** with **acetone**.
4. Apply **shaft glue** to the **spacer**.
5. Press the **idle pulley** onto the **spacer**, using a depth gauge to ensure correct positioning (see position Drawing).
6. Let it cure for 4 hours.

1.6 attachment

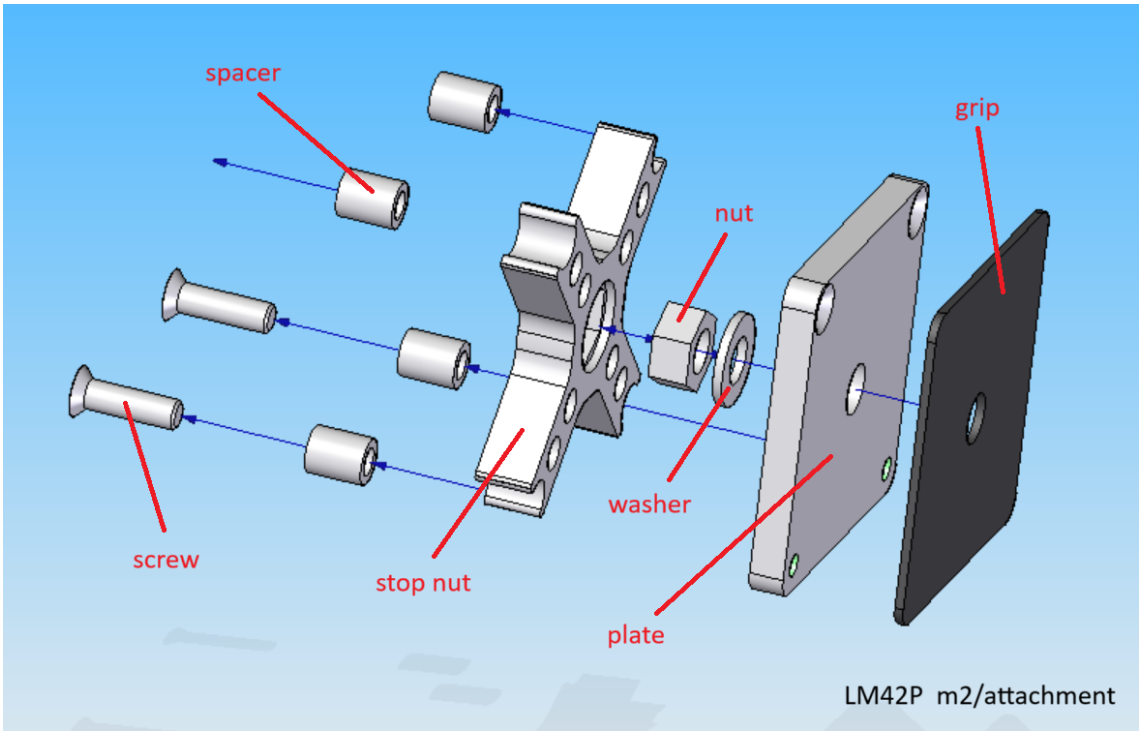


Figure 1.28: m2 attachment parts

1.6.1 Parts list

Table 1.9: Parts list of **attachment**

Qty	Part	Description	Material
1	**plate**	57 x 57 x 6	aluminium
1	**stop nut**	3D Printed	PLA
1	**nut**	M8	brass
1	**washer**	M8 x 8 x 35 mm	stainless steel
4	**spacer**	8 / 5 × 10 mm	aluminium
2	**screw**	M5 x 18 mm Torx flat head screw	stainless steel
1	**grip**	57 x 57	Griptape (skateboard)

1.6.2 Drawing

See Figure 1.29, page 54.

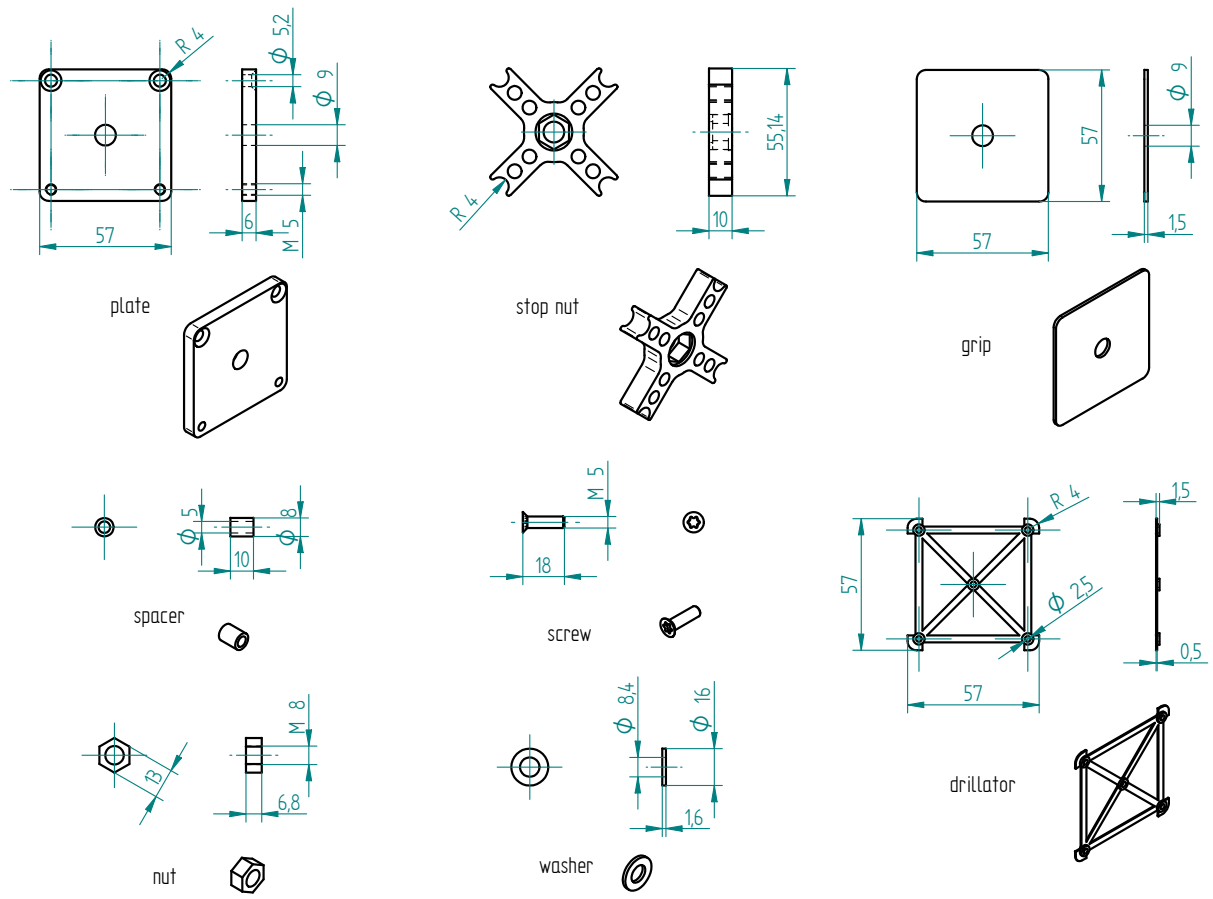


Figure 1.29: Drawing of the attachment parts

1.6.3 Manufacturing Instructions

Required Tools and Components

- 1x aluminium plate 57 x 57 x 6 mm ;
- 1x 3D printer ;
- 1x PLA ;
- 1x STL file (**stop nut**) ;
- 1x STL file (**drillator**) ;
- 2x clamp ;
- 1x scriber ;
- 1x file ;

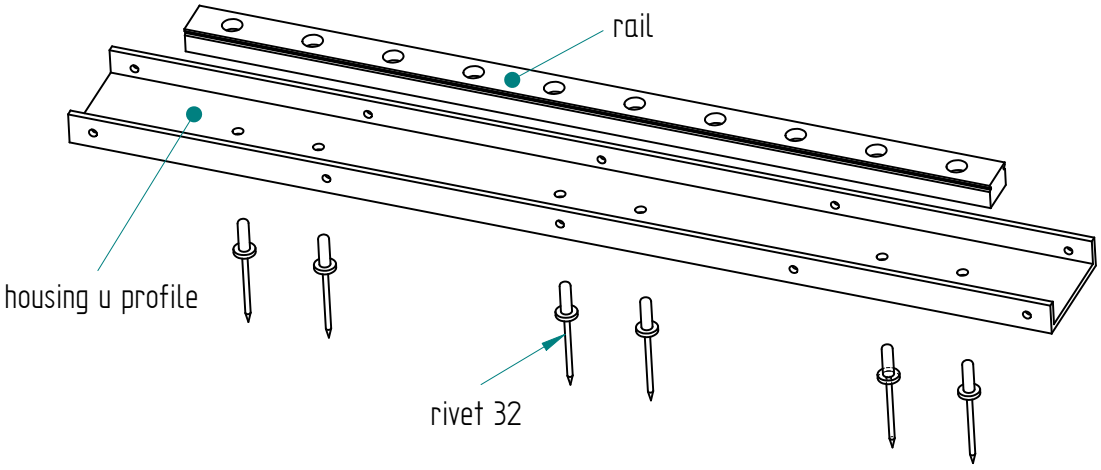
- 1x 2.5 mm drill bit ;
- 1x 5.2 mm drill bit ;
- 1x 4.2 mm drill bit ;
- 1x 9 mm drill bit ;
- 1x M5 tap ;
- 1x Griptape 57 x 57 mm (use for skate board) ;
- 1x drill press ;
- 1x driller.

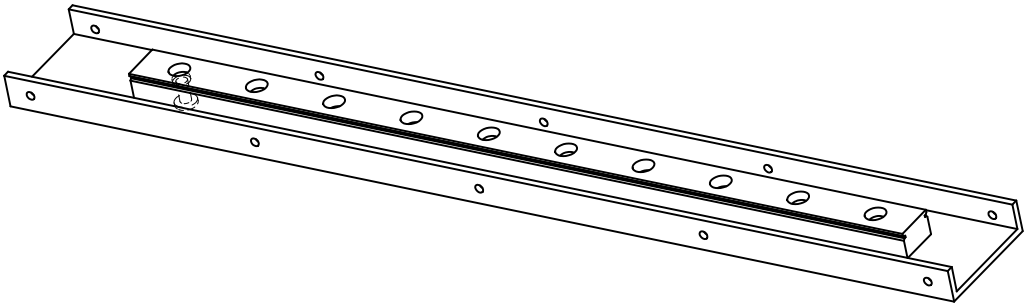
1. 3D print the **drillator** ;
2. 3D print the **stop nut** ;
3. clamp the **drillator** on the aluminium plate ;
4. scribe the 4x radii and the holes ;
5. drill and tap all holes ;
6. file the 4 radii ;
7. file the sharp edges ;
8. cut and drill the **grip**.

1.7 Assembling Instructions

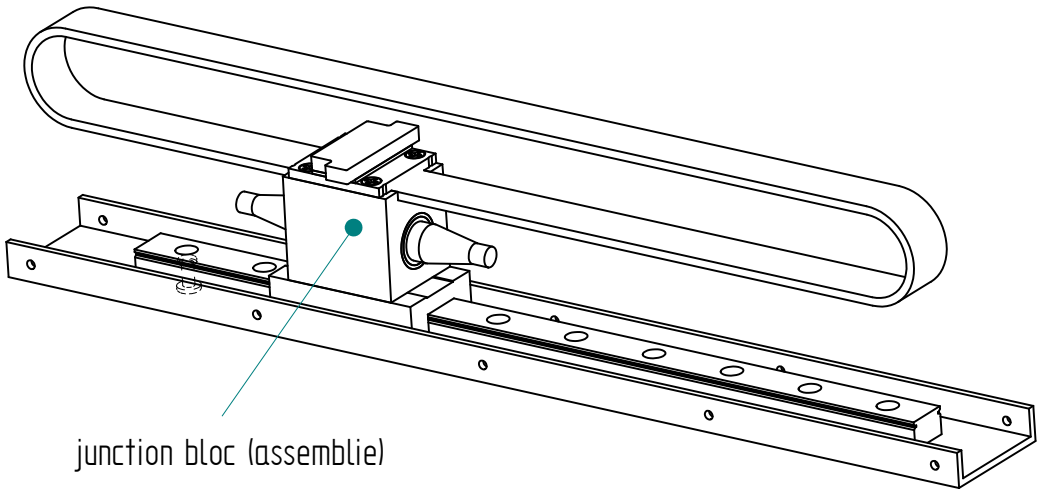
Remark All screws must be glued using threadlock glue.

1. Fabricate the shaped tools: the **tensionator** and the **drillator** (refer to section **tensionator** and **drillator**).
2. Rivet the **rail** onto the **housing U-profile**.

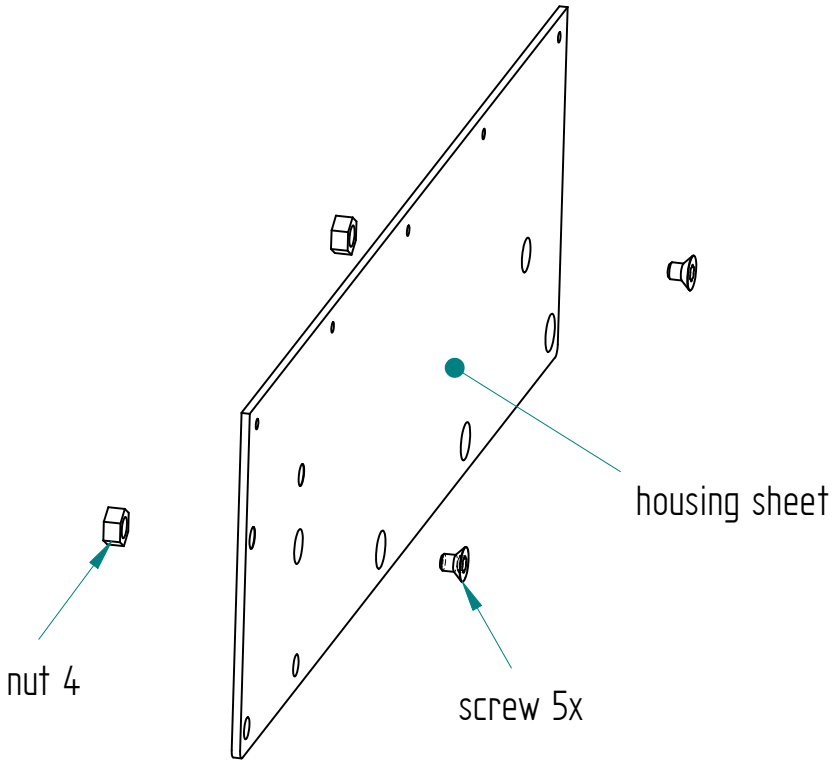


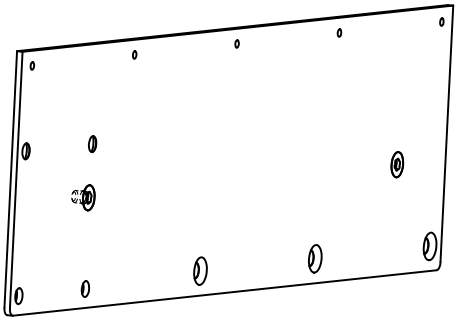


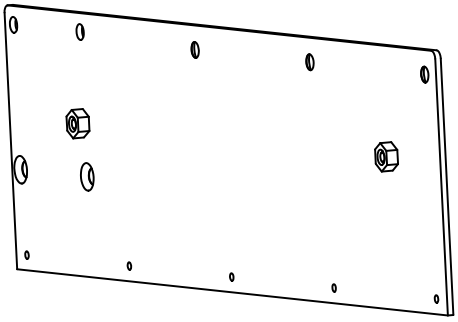
3. Slide the **junction block** (assembly) onto the **rail**.

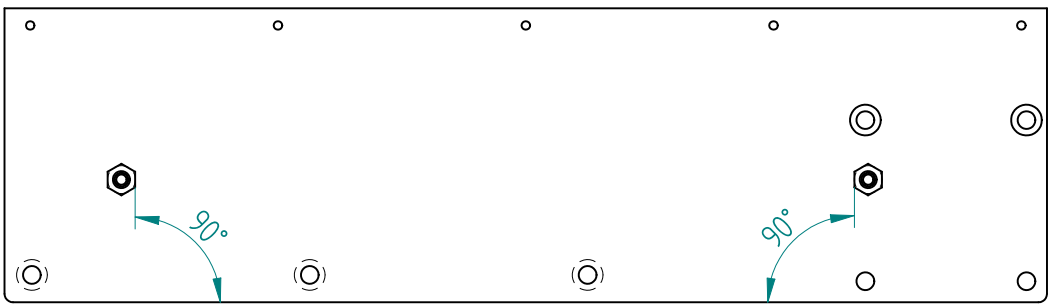


4. Mount the **stop screw nut**, ensuring proper alignment. Glue with **threadlock glue** and **mastic glue**. After curing, file the **5x screw** so it does not protrude.

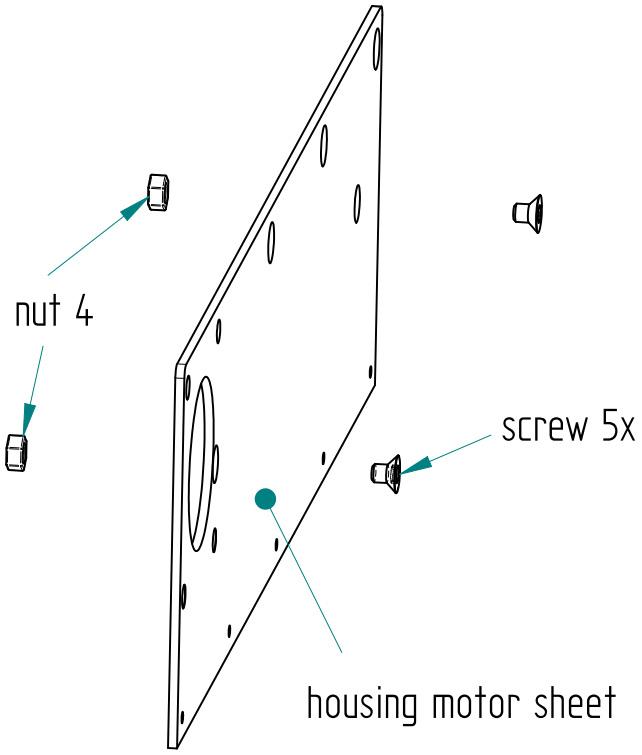


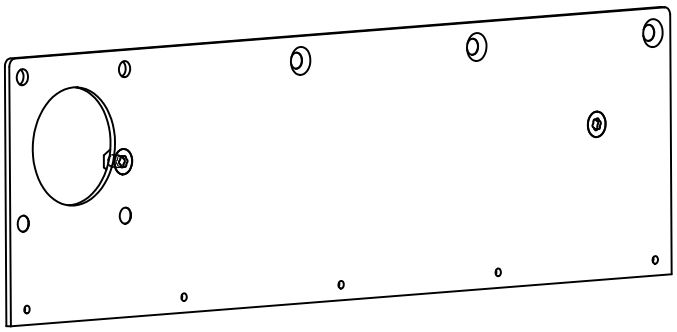


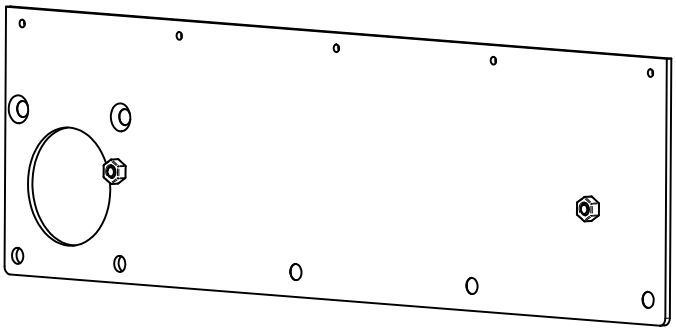


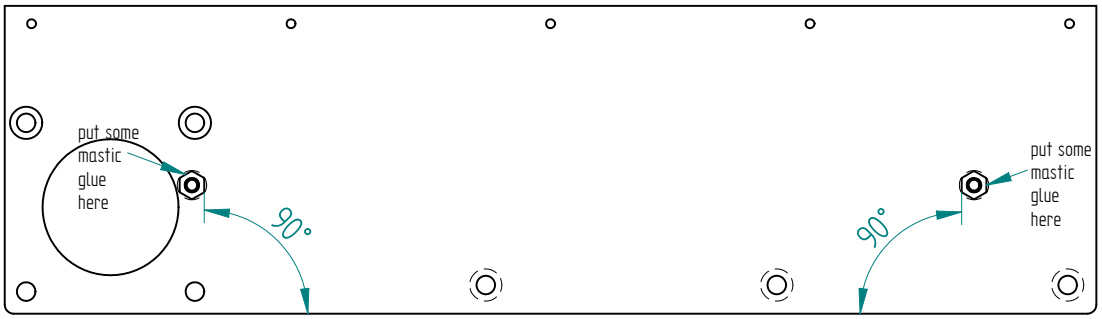


5. Repeat the previous step to mount the second **stop screw nut**.


nut 4
screw 5x
housing motor sheet

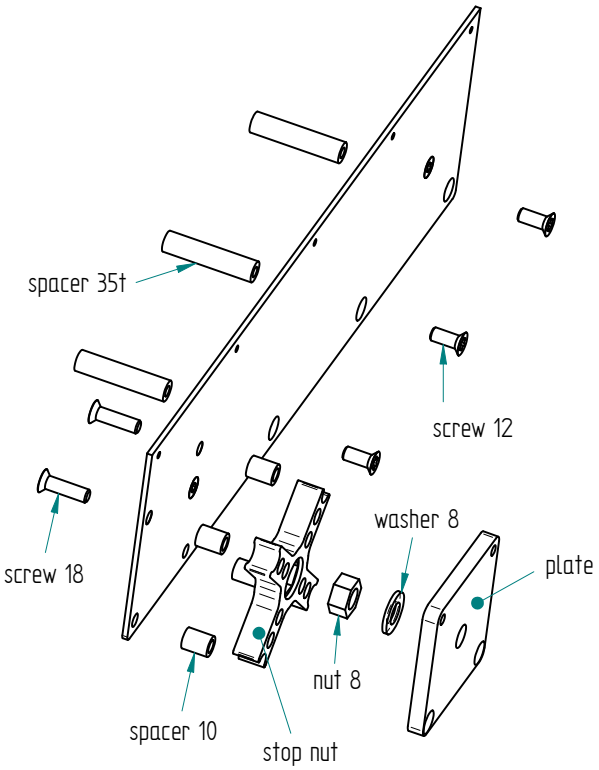


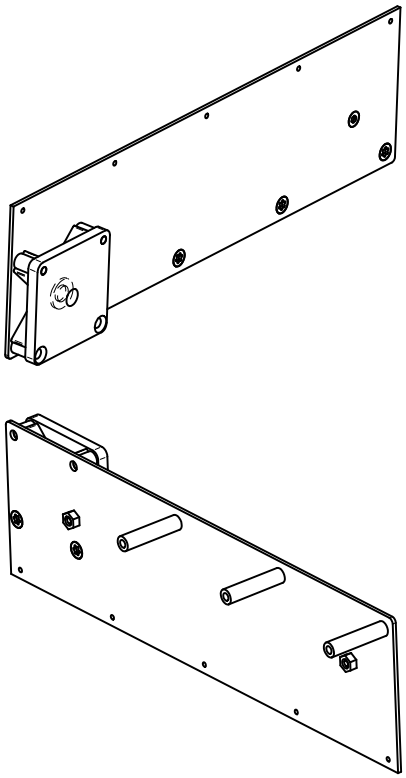




6. Assemble the following components:

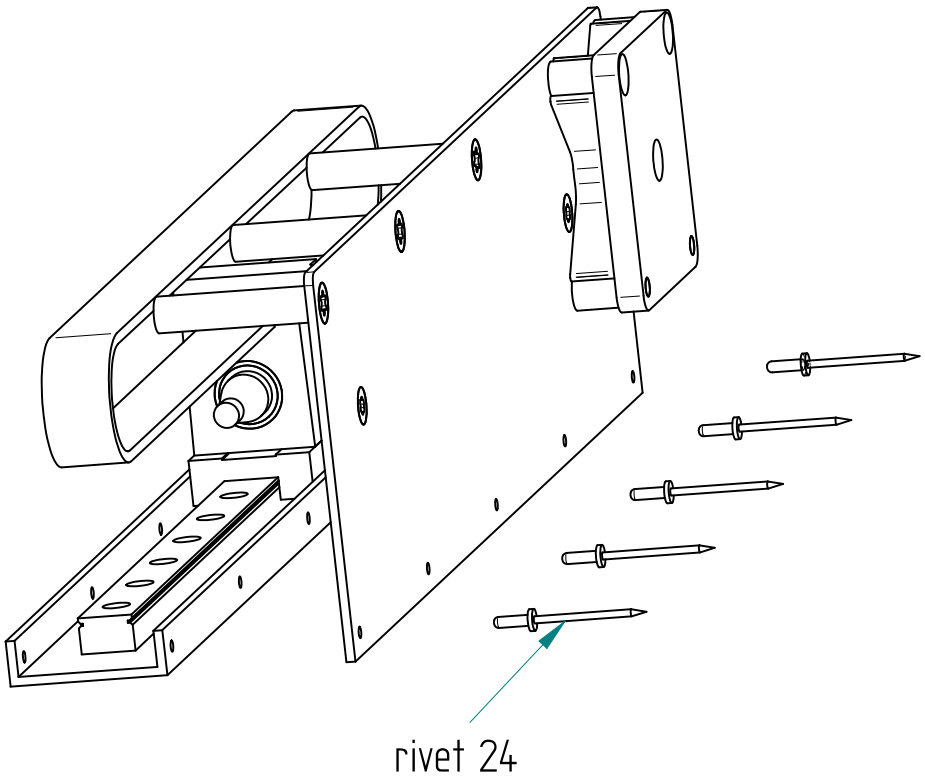
- 3 × **spacer 35**
- 3 × **screw 12**
- 4 × **spacer 10**
- 2 × **screw 18**
- 1 × **stop nut**
- 1 × **nut 8**
- 1 × **washer 8**
- 1 × **plate**

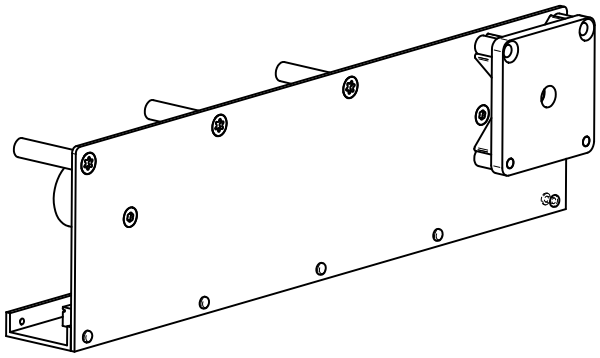


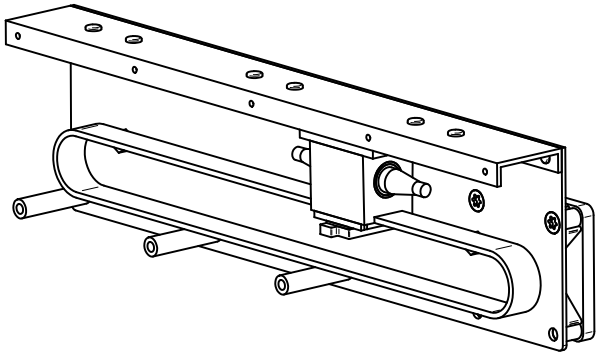


7. Rivet the following:

   - 5 × **rivet 24**





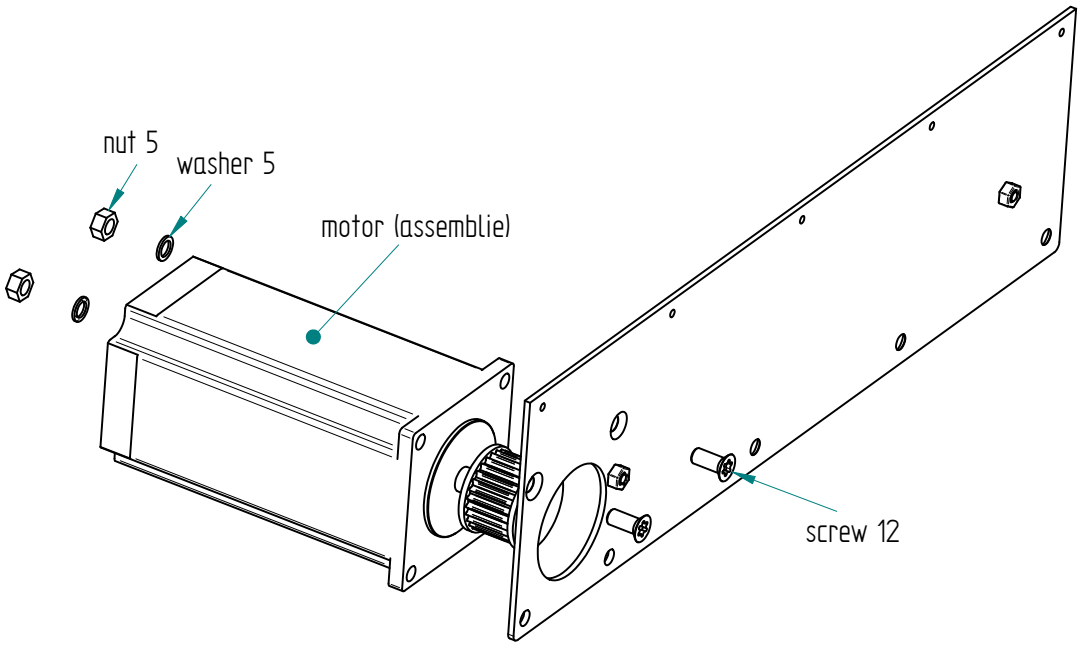


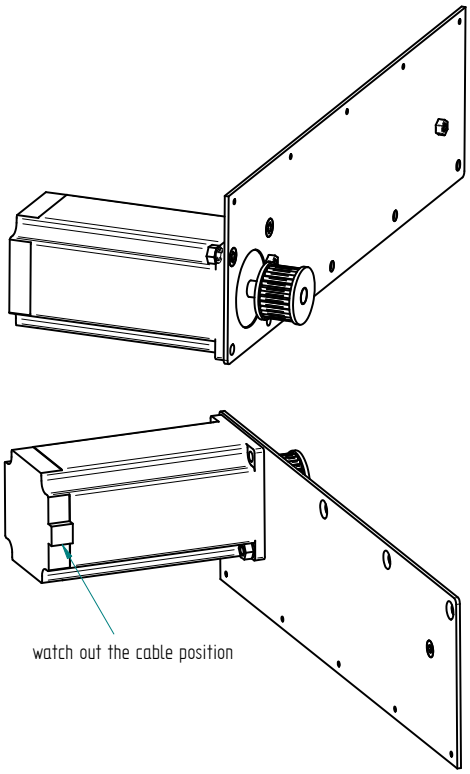
8. Secure the **motor** (assembly) with:

   - 2 × **screw 12**

- 2 × **washer 5**
- 2 × **nut 5**

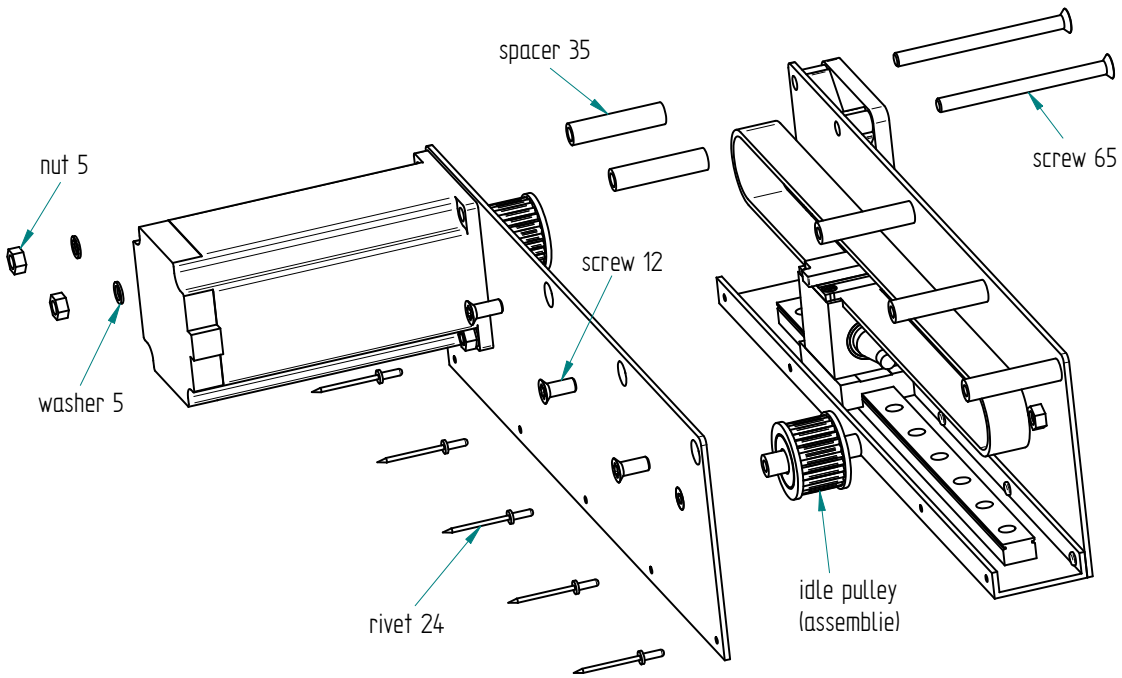
Ensure the cable is properly oriented.

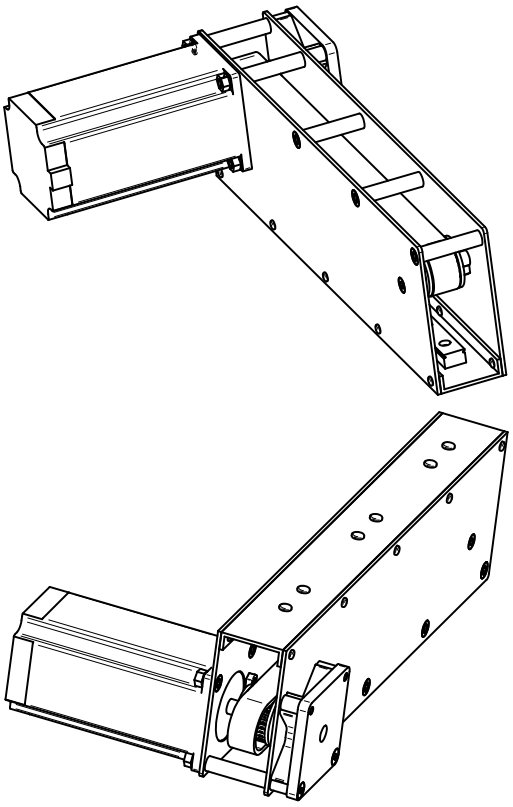




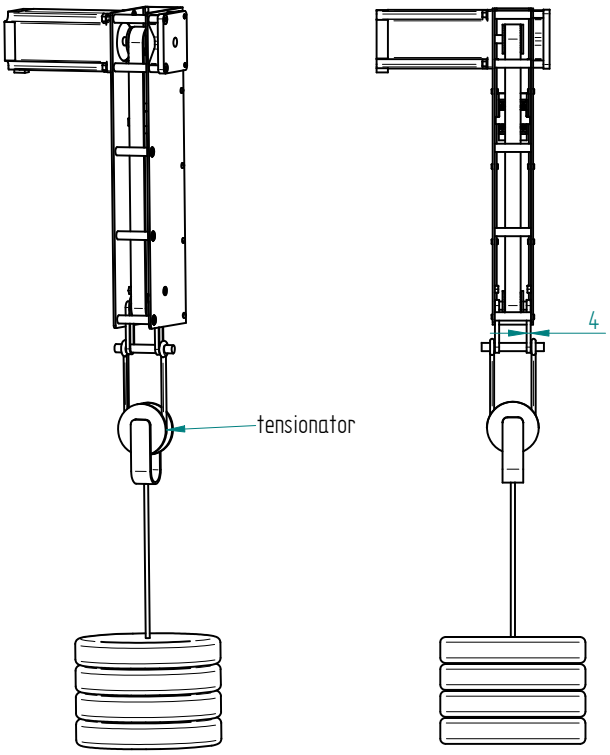
9. Close the housing using the **idle pulley** (assembly), with:

- 2 × **screw 65**
- 2 × **spacer 35**
- 2 × **washer 5**
- 2 × **nut 5**
- 3 × **screw 12**
- 5 × **rivet 24**
- 1 × **idle pulley** (assembly)



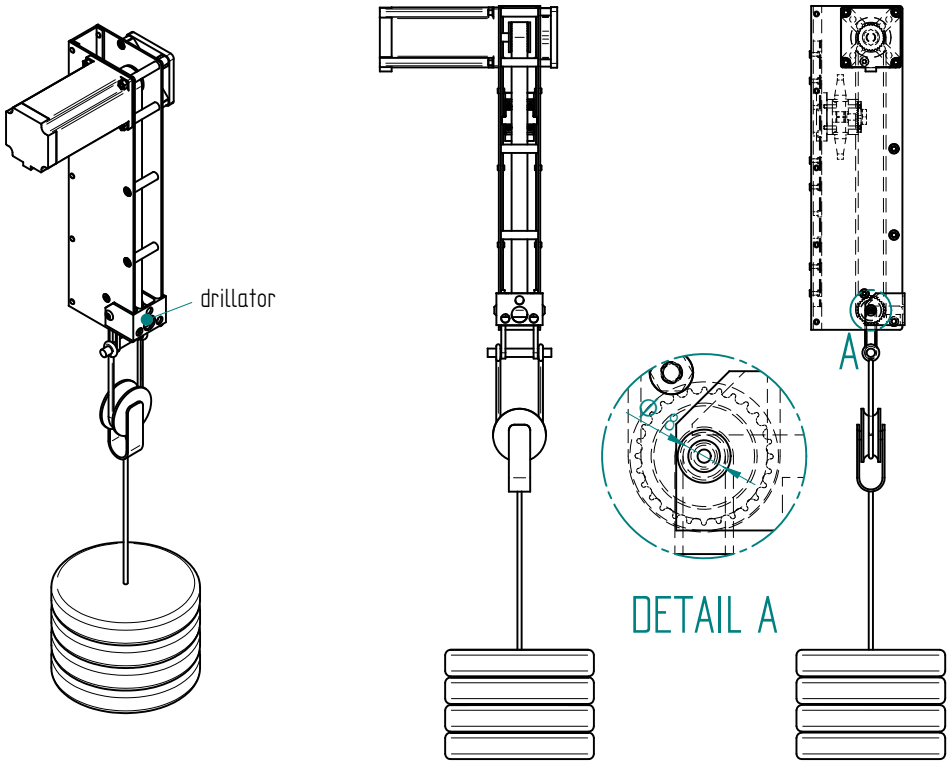


10. Attach the shaped tool **tensionator** to the **idle pulley** using 2 × **colson 4**.



11. Place a weight of approximately 17 kg (e.g., 11 × 1.5 L bottles).

12. Mount the shaped tool **drillator**.



13. Mark drill points using a **2.5 mm drill** on both sheets.
14. Drill with a **5 mm drill**, then chamfer the holes. *Test the depth using a screw.*
15. Tighten the **idle pulley** using 2 × **screw 12**.
16. Well Done you've finished the **m2** !

1.7.1 drillator

This section shows how to make the shaped tool named **drillator** The purpose of this tool is to point the holes of the **idle pulley** shaft during tensioning the **belt**.

Drawing

The figure 1.30, page 67, shows the drawing of the **drillator**.

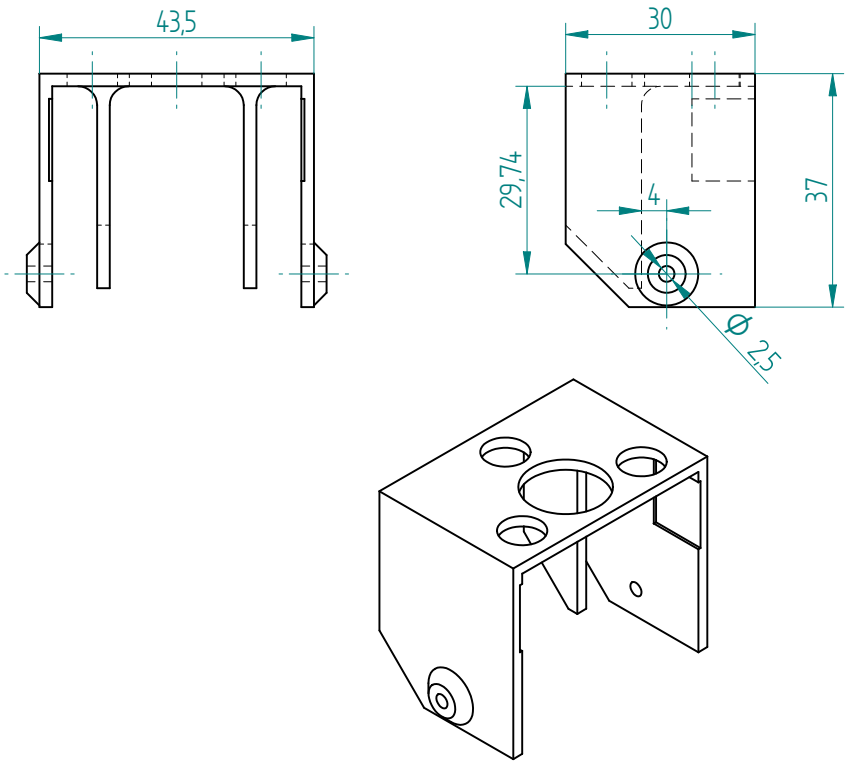


Figure 1.30: drawing of the **drillator**

Details

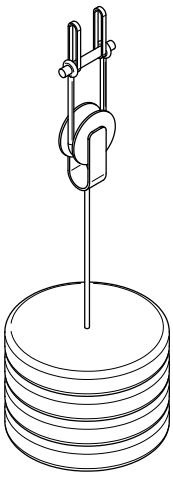
Quantity 1 ;

Material PLA ;

Manufacturing Instructions

1. 3d print the **drillator** the files are in the folder named **3d-print-files**.

1.7.2 tensionator



This section explains how to build the shaped tool called the **tensionator** for the assembly of the **m2** machine.

Drawing The figure 1.31, page 68, shows the drawing of the **tensionator** with all its elements.

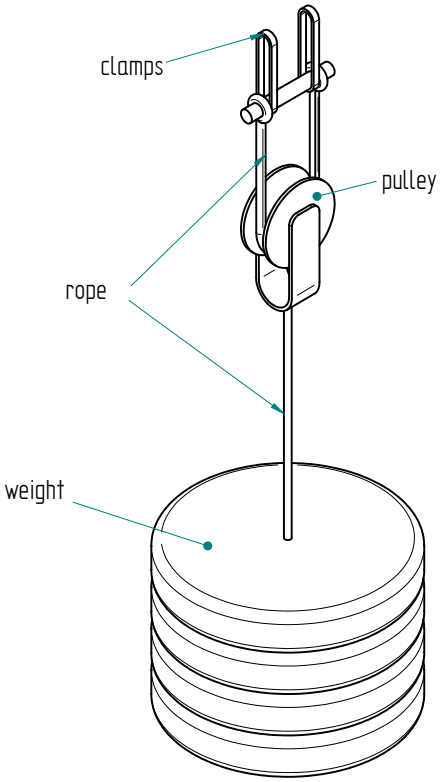


Figure 1.31: **tensionator** and its elements

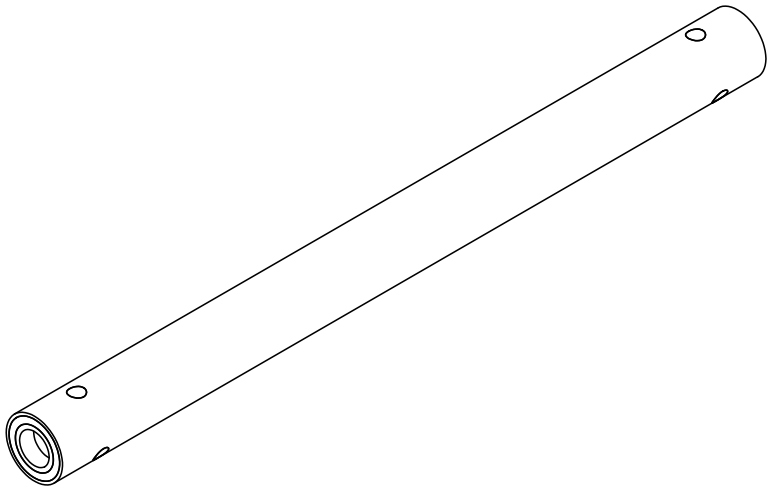
Table 1.10: Parts list of **tensionator**

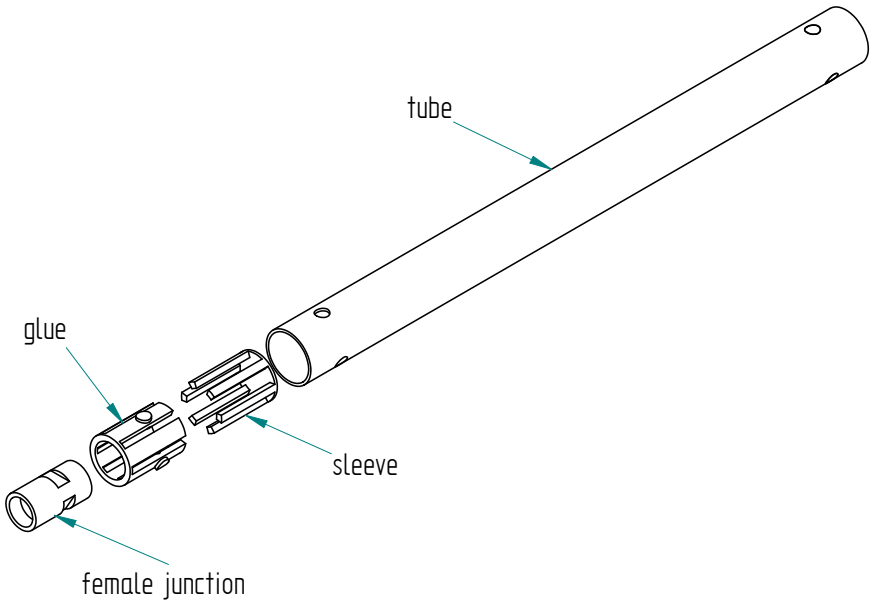
Qty	Part	Description	Material
1	pulley	D50 mm	-
1	colson	4 mm	-
2	rope	-	-
1	weight	17 kg	-

Chapter 2

m2 accessories

2.1 rod





2.1.1 Parts list

Table 2.1: Parts list of the **rod**

Qty	Part	Description	Material
1	tube	20/18,length: 250 mm	carbon
1	female junction	google : `pool cue junction`	brass
1	sleeve	3D printed	PLA
1	glue	resin, hardner, graphite powder	

2.1.2 Drawing

See Figure 2.1, page 73.

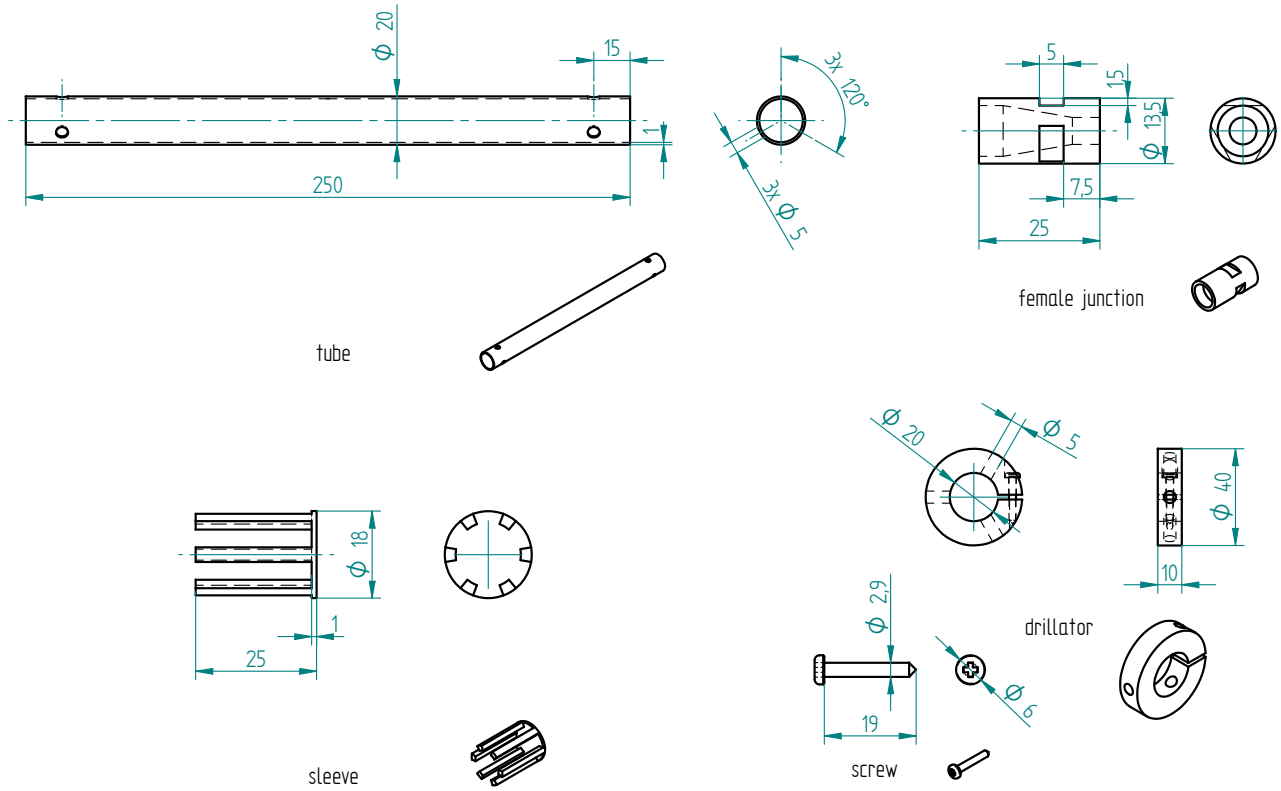


Figure 2.1: Drawing of the **rod** parts

2.1.3 Manufacturing Instructions

Required Tools and Components

- 1x carbon tube length: 500 mm ;
- 1x paper ;
- 1x tape ;
- 1x handsaw ;
- 1x perpendiculator ;
- 1x drillator ;
- 1x 5mm drill bit ;
- 1x driller ;

- 1x sandpaper ;
- 1x 3D printer ;
- 1x PLA filament ;
- 2x female junction ;
- 1x file ;

tube

1. Scribe a mark at the exact middle of the carbon tube.
2. Wrap a piece of paper around the tube and secure it with tape (to guide the cut).
3. Use a handsaw to cut the tube into two equal parts.
4. Make both ends of each tube perpendicular using the **perpendiculator** tool.
5. Remove the sharp edges with sandpaper.
6. Drill the 6 holes using the driller and the **drillator** tool (refer to the Drawing section).
7. Remove the sharp edges again with sandpaper.

sleeve

1. 3D print the part using the files located in the `3d-print-files` directory.
2. Chamfer the edges using a file.
3. Insert the female junction into the sleeve and gently push it into the tube. Adjust if there is too much friction or too large a gap.

female junction

1. File the three 5/1.5mm flats—see dimensions in the **Drawing** section.

2.1.4 Assembly Instructions

Required Tools and Components

- 1x hot glue ;
- 1x **male junction** ;
- 1x tape ;
- 1x scale ;
- 1x glue :
  - resine:

Brand ? ;
Type ?.

– hardner:

Brand ? ;
Type ?.

- 1x graphite powder :

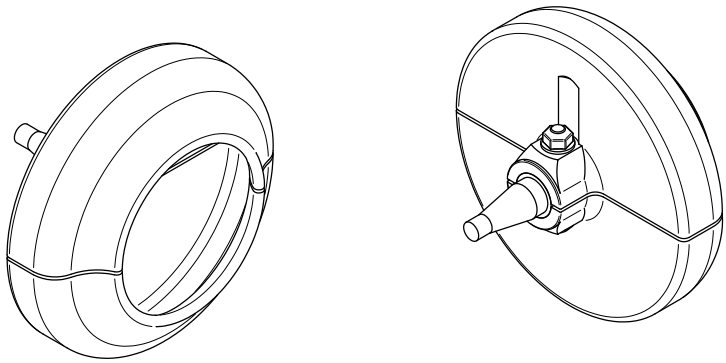
  Brand Suter Kunstoff AG ;
  Type West Graphit-Pulver 423.

- 1x clamp ;
- 1x piano wire ;
- 1x oven ;
- 1x **perpendicalor**.

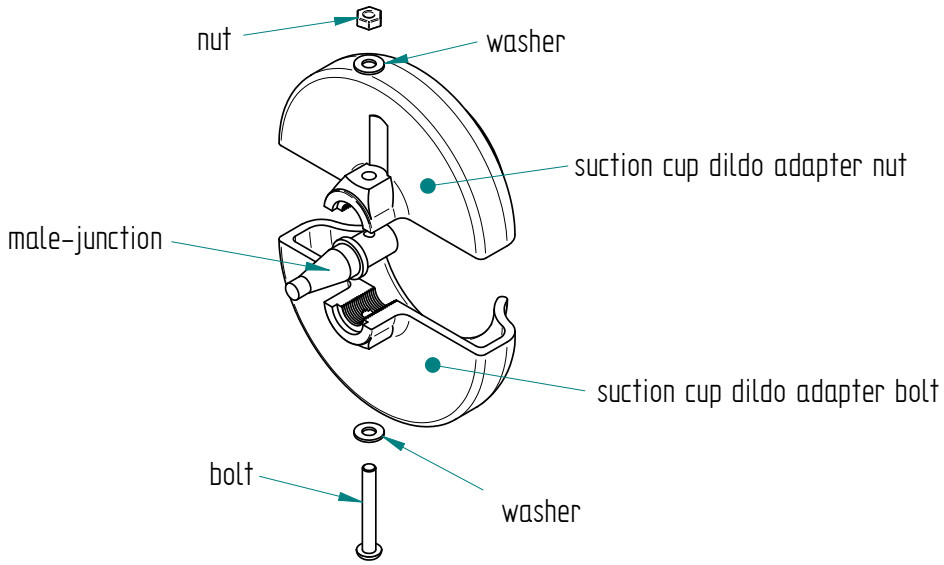
1. Screw the **male junction** into the **female junction**.
2. Seal the hole with hot glue.
3. Trim any excess hot glue using a scalpel.
4. Unscrew the **male junction**.
5. Thoroughly clean the outside and top of the **female junction** with acetone.
6. Seal the hole with tape.
7. Using a scalpel, carefully cut the tape around the **female junction**.
8. Insert the **female junction** into the **sleeve**, ensuring the flat side aligns with the canals inside the **sleeve**.
9. Push the assembly into the **tube** until the **female junction** is aligned with the end of the **tube**. Use a ruler for accuracy. Press on the tape — it's normal for the **female junction** to move slightly inward due to the tape's thickness.
10. Wrap tape around the end of the **tube**, with the tape's edge extending about 1 mm above the end of the **tube**.
11. To glue two **female junctions**, prepare the following mixture:
    - 1.5 g of **hardener** ;
    - 3.75 g of **resin** ;
    - 1.125 g of **graphite powder**.
12. Prepare **glue**, as described in the shaped-parts section, and mix it with **graphite powder**.

13. Use a clamp to hold the **tube** vertically.
14. Pour the glue mixture above the tape, letting it slightly overflow past the end of the tube.
15. Use piano wire to enter each canal of the **sleeve**, removing any bubbles and ensuring **glue** flows properly into the canals.
16. Let the **glue** set for 2 hours.
17. After 2 hours, check the level of the composite. Add more if necessary.
18. Allow to cure for 24 hours, or place in an oven to accelerate curing.
19. Use the **perpendiculator** to grind the end of the **tube** until the tape sealing the **female junction** is removed (you should see a shiny ring appear).
20. Repeat the same steps for the other end of the **tube**.

2.2 suction cup dildo adapter



This section explain how to build the **suction cup dildo adapter** for the **m2** machine.



2.2.1 Parts list

Table 2.2: Parts list of **suction-cup-adapter**

Qty	Part	Description	Material
1	**suction cup dildo adapter nut**	3D printed	PLA
1	**suction cup dildo adapter bolt**	3D printed	PLA
1	**male junction**	google : pool cue junction	brass

continued on next page ...

... continued

Qty	Part	Description	Material
1	**bolt**	M4 x 30 mm	stainless steel
1	**nut**	M4	brass
2	**washer**	M4	stainless steel

2.2.2 Drawing

See Figure 2.2, page 78.

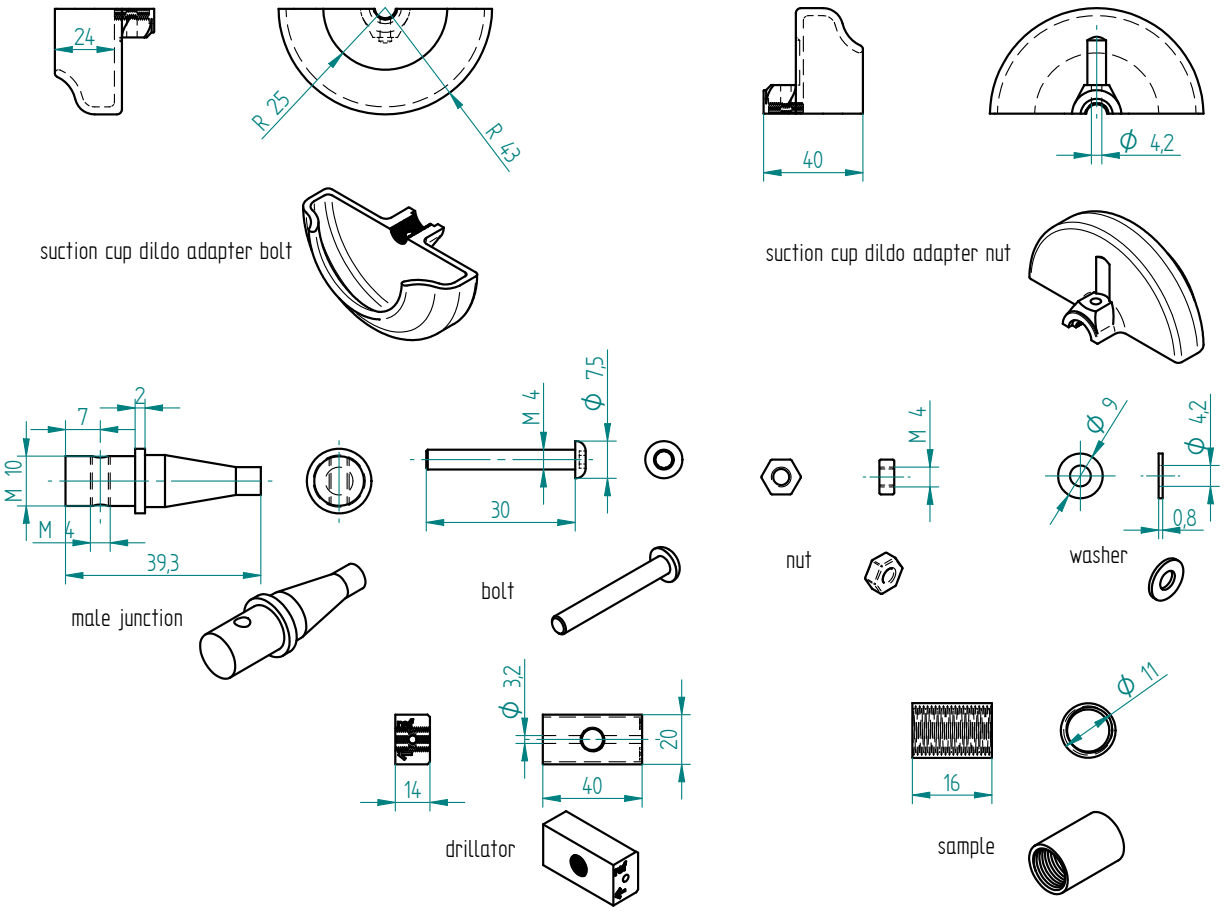


Figure 2.2: Drawing of the suction cup dildo adapter parts

2.2.3 Required Tools and Components

- 1x 3D printer ;
- 1x CAD software (to ajuste M10 tap in case) ;
- 1x PLA ;
- 1x STL file **suction cup dildo adapter nut** ;
- 1x STL file **suction cup dildo adapter bolt** ;

- 1x STL file **drillator** ;
- 1x STL file **sample** ;
- 1x **male junction** ;
- 1x **bolt** ;
- 2x **washer** ;
- 1x **nut** ;
- 1x file ;
- 1x 3.2 mm drill bit ;
- 1x chamfer mill ;
- 1x M4 tap ;
- 1x tap wrench ;
- 1x boltdriver ;
- 1x drill press ;
- 1x driller ;
- 1x water pump pliers ;
- 1x allen key ;
- 1x threaderlock glue ;
- 1x bench vise.

2.2.4 Manufacturing Instructions

1. Skip the next three steps if all 3D printers used print with the same accuracy as an Ultimaker.
2. 3D print the **sample**.
3. Test if the M10 tap fits into the **sample**.
4. Adjust the M10 tap size on the **suction cup dildo adapter nut**, **suction cup dildo adapter bolt**, and **drillator** 3D models as needed.
5. **Remark :** Before printing the **suction cup dildo adapter nut** and the **suction cup dildo adapter bolt**, adjust the starting position of the M4 thread. The **drillator** was originally designed for a 2mm **male junction**, but since the actual **male junction** is located at 0.5 mm, I had to shift the thread start by 0.5 mm to compensate. the **male juction** was not at 2mm but at 2.5mm. 3D print the **suction cup dildo adapter nut**, **suction cup dildo adapter bolt**, and **drillator**.

6. Screw the **male junction** into the **drillator** (the large diameter with a width of 2 mm should be flush against the reference plane). Use water pump pliers.
7. On a drill press, drill a 3.2 mm hole.
8. File or chamfer the hole.
9. Tap an M4 thread.
10. Assemble the **male junction** and **suction cup dildo adapter bolt** with the **bolt**. Don't forget to apply thread locker.

2.3 tenga adapter

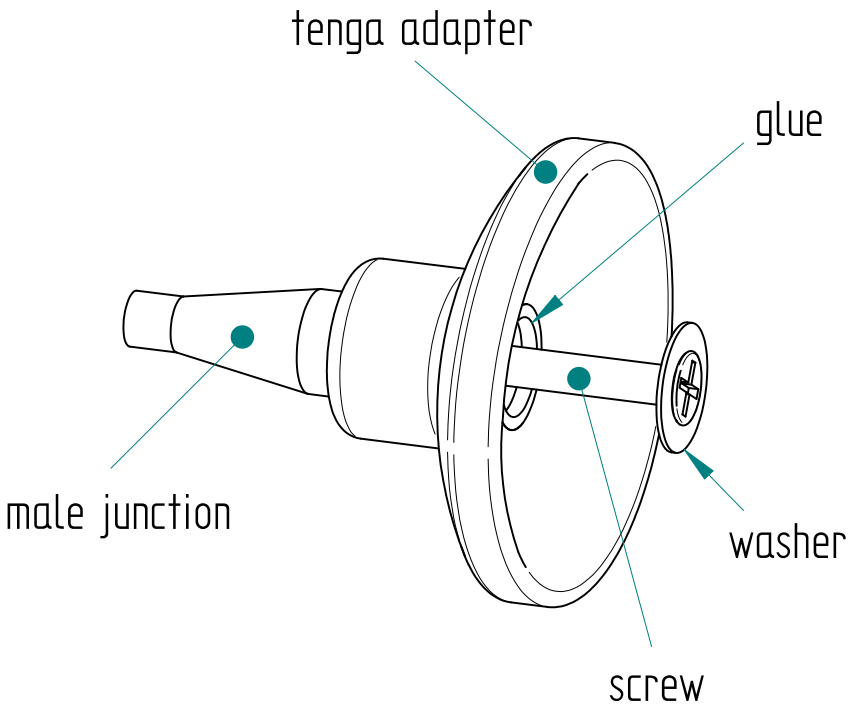


Figure 2.3: m2 accessories tenga-adapter parts

2.3.1 Parts list

Table 2.3: Parts list of **tenga-adapter**

Qty	Part	Description	Material
1	**tenga adapter**	3D Printed	PLA
1	**male junction**	M10 x 39.3 mm	PLA
1	**glue**	casted	epoxy and grafite powder
2	**screw**	M4 x 25 mm Torx flat head screw	stainless
1	**washer**	M7 x 13 x 0.5 mm	stainless steel
1	**drillator**	3D Printed	PLA

2.3.2 Drawing

See Figure 2.4, page 82.

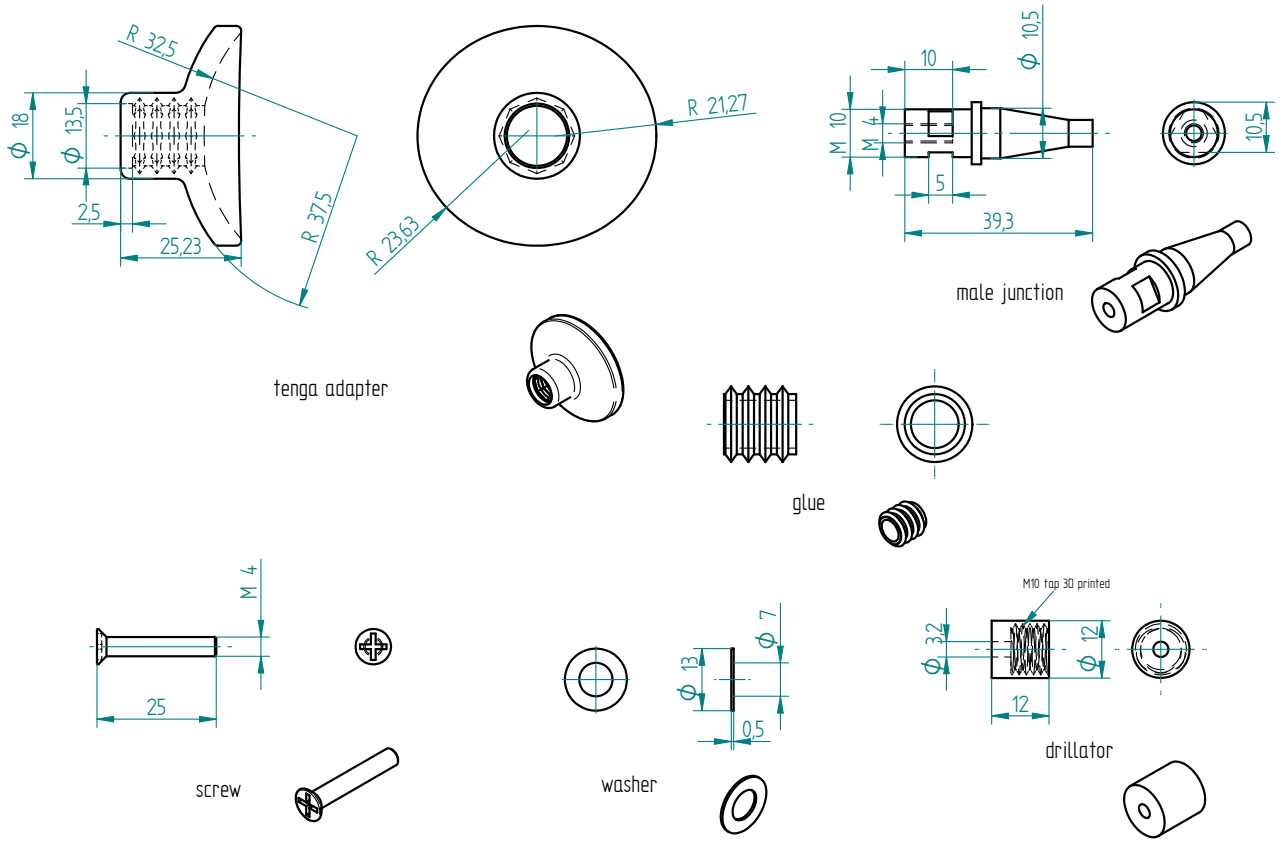


Figure 2.4: Drawing of the tenga adapter parts

2.3.3 Required Tools and Components

- 1x 3D printer ;
- 1x PLA ;
- 1x STL file (**tenga adapter**) ;
- 1x STL file (**drillator**) ;
- 1x **male junction** ;
- 1x **female junction** ;
- 1x screwdriver ;
- 1x 3.2 mm drill bit ;
- 1x 4.2 mm drill bit ;

- 1x chamfer cutter ;
- 1x M4 tap ;
- 1x left-hand tap ;
- 1x drill press ;
- 1x driller ;
- 1x file ;
- 1x tape ;
- 1x cutter ;
- 1.5 g of hardener ;
- 3.75 g of resin ;
- 1.125 g of grafite powder ;
- 1x wood chisel.

2.3.4 Manufacturing Instructions

See also video : `https://youtu.be/Vnh40WeMOiQ`

1. 3D print the **drillator**.
2. 3D print the **Tenga adapter**.
3. Drill a 4.2 mm hole in the Tenga Fleshlite.
4. Insert the **male junction** into the **female junction**.
5. Using a drill press, drill a 3.2 mm hole.
6. Tap an M4 thread into the hole.
7. File three flat surfaces on the M10 thread.
8. Wrap tape around the M4 thread.
9. Trim the tape using a cutter.
10. Insert the **male junction** into the **Tenga adapter**.
11. Prepare the **glue** mixture:
    - 1.5 g of hardener;
    - 3.75 g of resin;
    - 1.125 g of graphite powder.
12. Pour the **glue** into the assembly.

13. Remove any excess glue from the top of the **male junction**.
14. Assemble the Tenga Fleshlite using the **screw**.

2.4 glass dildo adapter

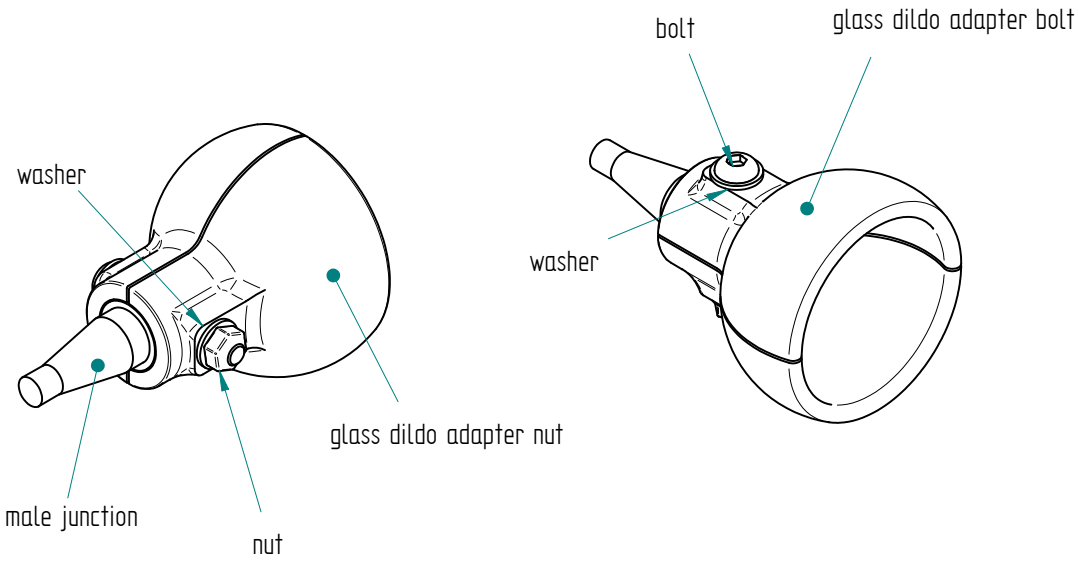


Figure 2.5: m2 accessories glass dildo adapter parts

2.4.1 Parts list

Table 2.4: Parts list of **glass dildo adapter**

Qty	Part	Description	Material
1	**glass dildo adapter bolt**	3D Printed	PLA
1	**glass dildo adapter nut**	3D Printed	PLA
1	**male junction**	M10 x 39.3 mm	PLA
1	**bolt**	M4 x 30 mm Torx flat head screw	stainless steel
2	**washer**	M4 x 9 x 0.8 mm	stainless steel
1	**nut**	M4 x 3 mm	stainless steel

2.4.2 Drawing

See Figure 2.6, page 86.

Remark : The position of 6 was previously at 4 mm, and a gap of 0.25 mm has been added. All 3D print files have already been updated accordingly, so the parts are ready for printing with these modifications.

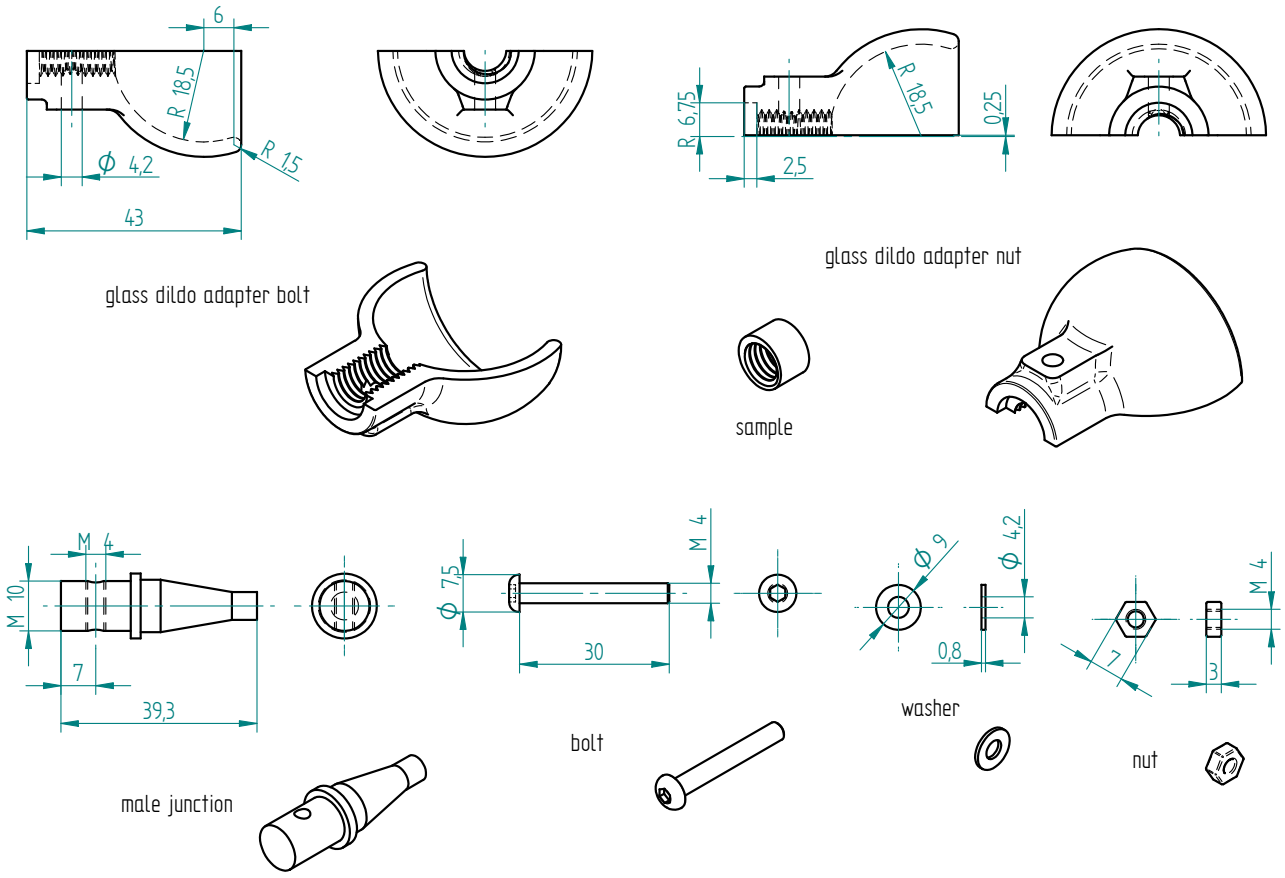


Figure 2.6: Drawing of the glass dildo adapter parts

2.4.3 Required Tools and Components

- 1x 3D printer ;
- 1x PLA ;
- 1x STL file (**glass dildo adapter**) which include both bolt and nut sides ;
- 1x STL file (**sample**) ;
- 1x STL file (**drillator**) ;
- 1x **male junction** ;
- 1x screwdriver ;

- 1x 3.2 mm drill bit ;
- 1x M4 tap ;
- 1x M10 tap ;
- 1x left-hand tap ;
- 1x drill press ;
- 1x driller ;
- 1x file ;
- 1x clamp ;
- 1 x 7 mm open-end wrench ;
- 1x 0.5 mm of sheet ;
- 1x threadlocker (light one).

2.4.4 Manufacturing Instructions

See also video : `https://youtube.com/shorts/h1XuS6wZHZM`

1. 3D print the **sample** and check if the M10 tap of the **male junction** fits snugly into the **sample** without any gap.
2. Adjust the M10 tap on the **drillator** model.
3. 3D print the **drillator**.
4. Adjust the M10 tap on the **glass dildo adapter** model (both nut and bolt sides).
5. 3D print the **glass dildo adapter**.
6. Place a 0.5 mm sheet between the **glass dildo adapter** parts.
7. Clamp all components together.
8. Tap the M10 thread.
9. Screw the **male junction** into the **drillator**.
10. Using a drill press, drill a 3.2 mm hole from both sides.
11. Tap an M4 thread into the hole.
12. File the sharp edges of the M10 thread.
13. Insert the **male junction** into the **glass dildo adapter bolt**.
14. Apply threadlocker to the **bolt**, add the **washer**, and tighten everything.
15. Assemble the **glass dildo adapter nut** with a **washer** and a **nut**.

2.5 vac u lock adapter

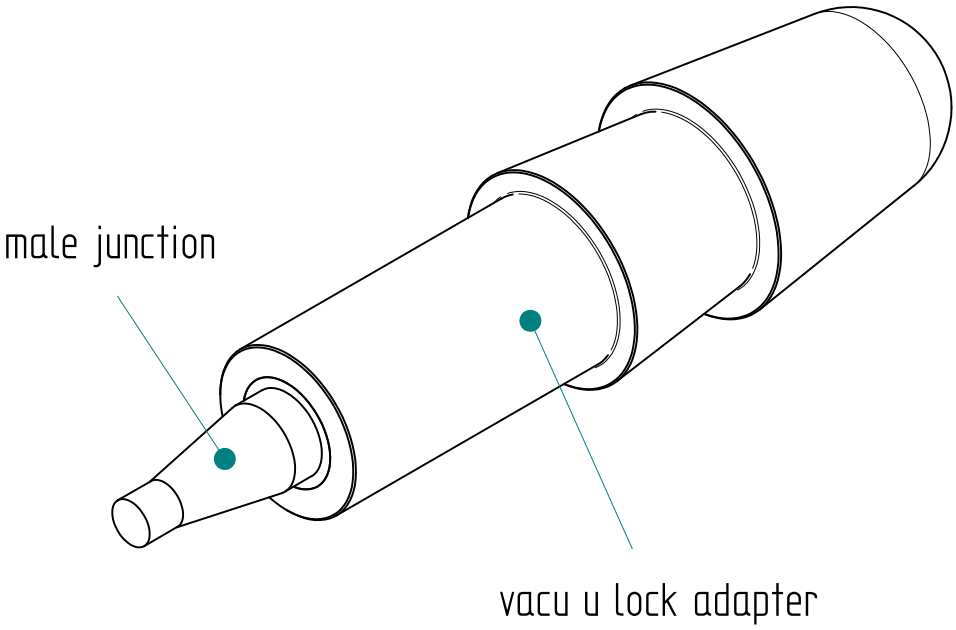


Figure 2.7: m2 accessories vac u lock adapter parts

2.5.1 Parts list

Table 2.5: Parts list of **vac u lock adapter**

Qty	Part	Description	Material
1	**vac u lock adapter**	molded	composite
1	**male junction**	M10 x 39.3 mm	brass

2.5.2 Drawing

See Figure 2.8, page 89.

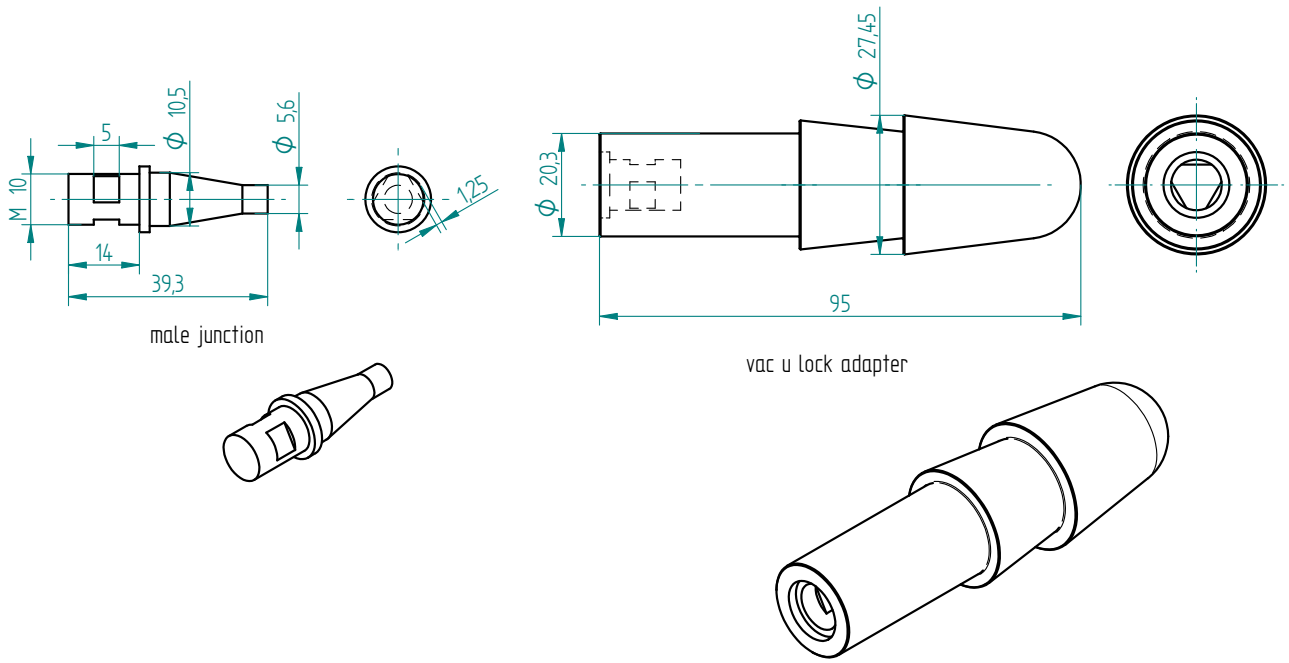


Figure 2.8: Drawing of the vac u lock adapter parts

2.5.3 Required Tools and Components

- 1x 3D printer ;
- 1x PLA ;
- 1x STL file (**mold**) ;
- 1x STL file (**cover**) ;
- 1x **male junction** ;
- 1x file ;
- ? g of hardener ;
- ? g of resin ;
- ? g of grafite powder ;

- 1x scale ;
- 1x release agent ;
- 1x 1s lipo battery or one AA battery ;
- 1x wooden chisel.

2.5.4 Manufacturing Instructions

See also video : not yet done

1. Get the **moldator** ready (see Section *moldator*).
2. 3D print the **mold**.
3. Preheat the oven to 40,°C.
4. Apply release agent inside the **mold**.
5. Wait 30 minutes.
6. Prepare the composite mixture:
   - ?,g hardener;
   - ?,g resin;
   - ?,g graphite powder.
7. Insert the **male junction** into the **cover**.
8. Pour the composite into the **mold**.
9. Gently close the **mold** with the **cover**.
10. Clamp the **mold** onto the **moldator**.
11. Connect the battery to the **motor**.
12. Place everything inside the oven.
13. Cure for 4 hours.
14. Use a wooden chisel to open the **mold**.

2.5.5 moldator

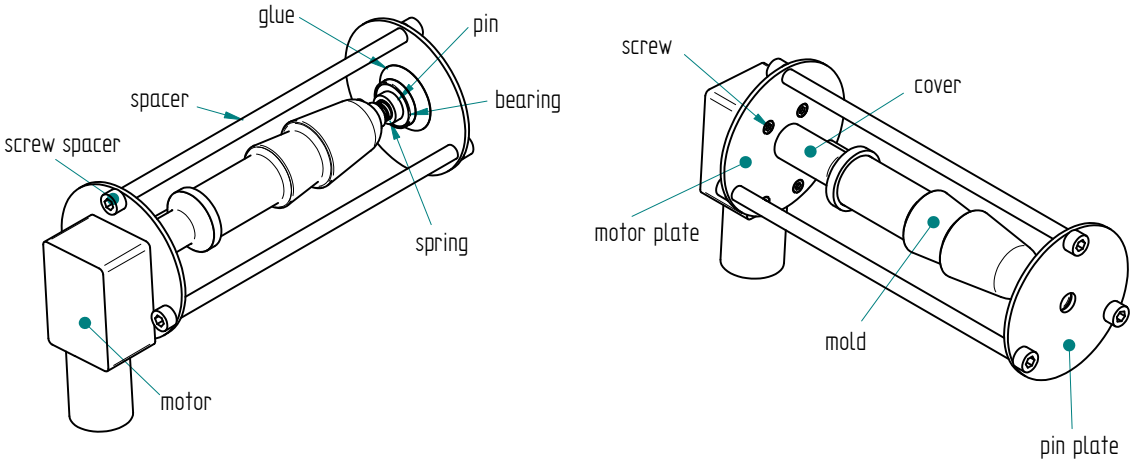


Figure 2.9: m2 accessories vac u lock adapter moldator parts

Parts list

Table 2.6: Parts list of **vac u lock adapter moldator**

Qty	Part	Description	Material
1	**motor**	standard (worm gear)	-
1	**motor plate**	64 x 2 mm	aluminium
1	**pin plate**	64 x 2 mm	aluminium
3	**spacer**	6 x 4 x 149.15 mm	aluminium
6	**screw spacer**	M5 x 12 mm	stainless steel
3	**screw**	M3 x 8 mm	stainless steel
1	**mold**	3D printed	PLA
1	**cover**	3D printed	PLA
1	**drillator**	3D printed	PLA

Drawing

See Figure 2.10, page 92 and Figure 2.11, page 93.

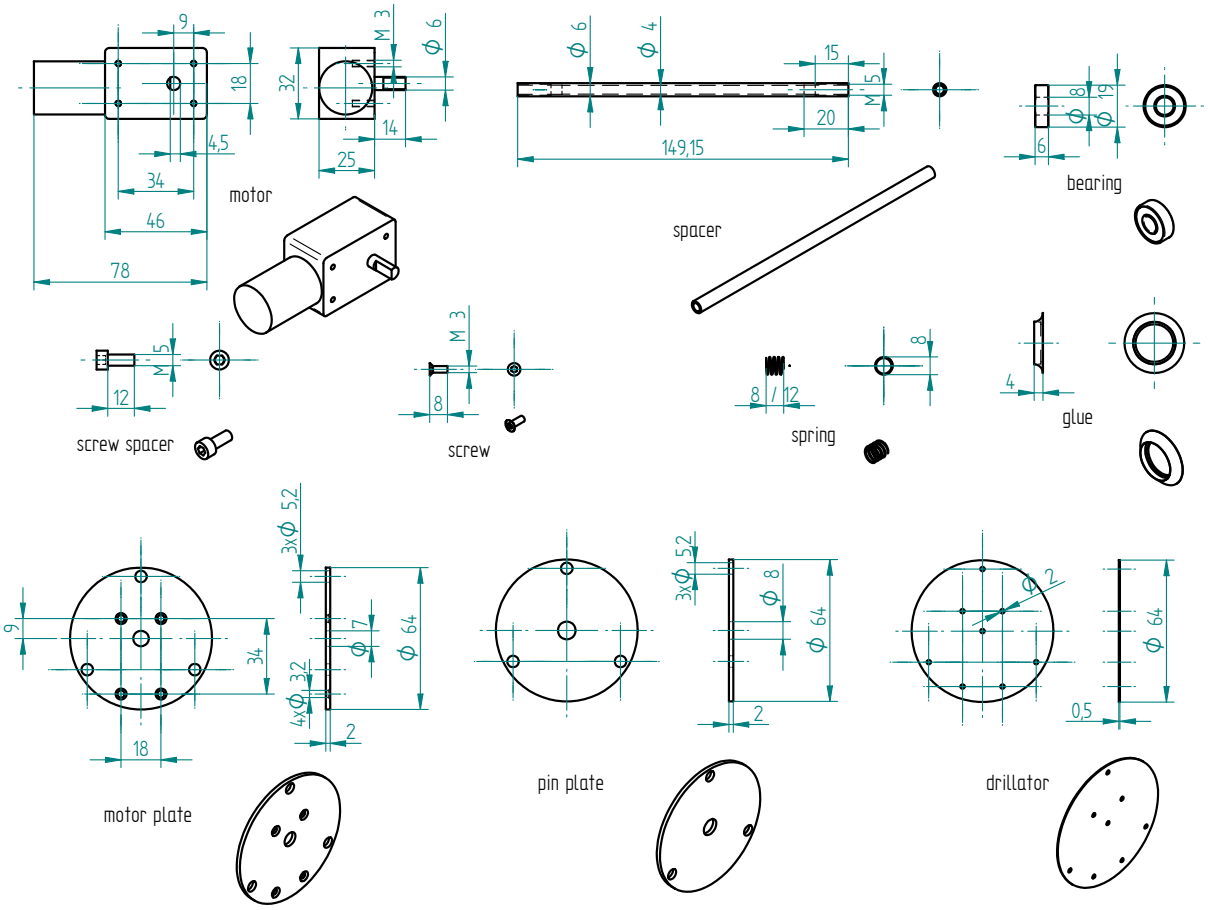


Figure 2.10: Drawing of the vac u lock adapter moldator parts

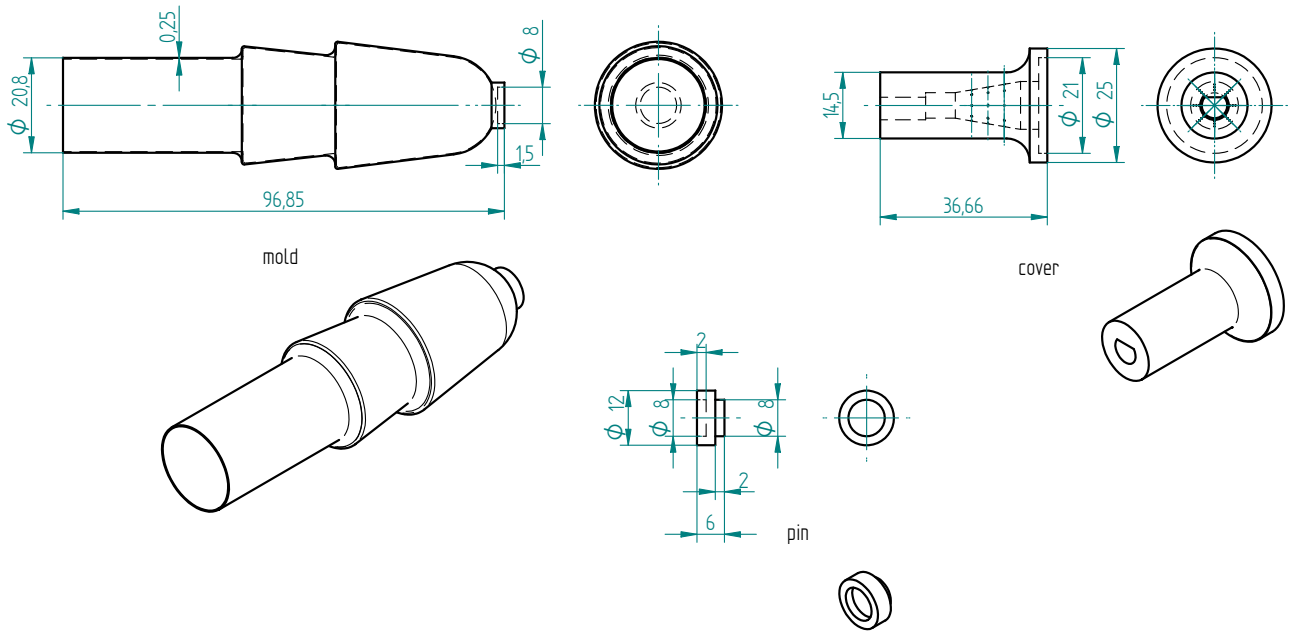


Figure 2.11: Drawing of the vac u lock adapter moldator parts (2)

Required Tools and Components

- 1× 3D printer ;
- 1× PLA spool ;
- 1× STL file (**drillator**) ;
- 1× 2,mm aluminium sheet ;
- 1× screwdriver ;
- 2× clamps ;
- 1× Allen key ;
- 1× 2,mm drill bit ;
- 1× 4.2,mm drill bit ;
- 1× 5.2,mm drill bit ;
- 1× chamfer cutter ;
- 1× M5 tap ;
- 1× left-hand tap ;
- 1× drill press ;
- 1× driller ;
- 1× file ;
- 1× scriber ;
- 1x jigsaw ;
- 1× 8×6,mm aluminium tube (min length 460,mm) ;
- 1× gauge ;
- 1× handsaw ;
- 1× **perpendiculator**.

2.5.6 Manufacturing Instructions

See also video : `https://youtu.be/Vnh40WeMOiQ`

1. 3D print the **drillator**.
2. 3D print the **cover**.
3. Clamp the **drillator** on the 2 mm aluminium sheet at a corner.
4. Point with a 2 mm drill bit.
5. Scribe the cercle around the **drillator**.
6. Drill all holes (see the drawing).
7. Saw with a jig saw the ouside cirle.
8. Repeat the five precedent points for the other **plate**.
9. Shape the **spacer**.
10. Assemble every thing like on the figure.

Chapter 3

power unit p

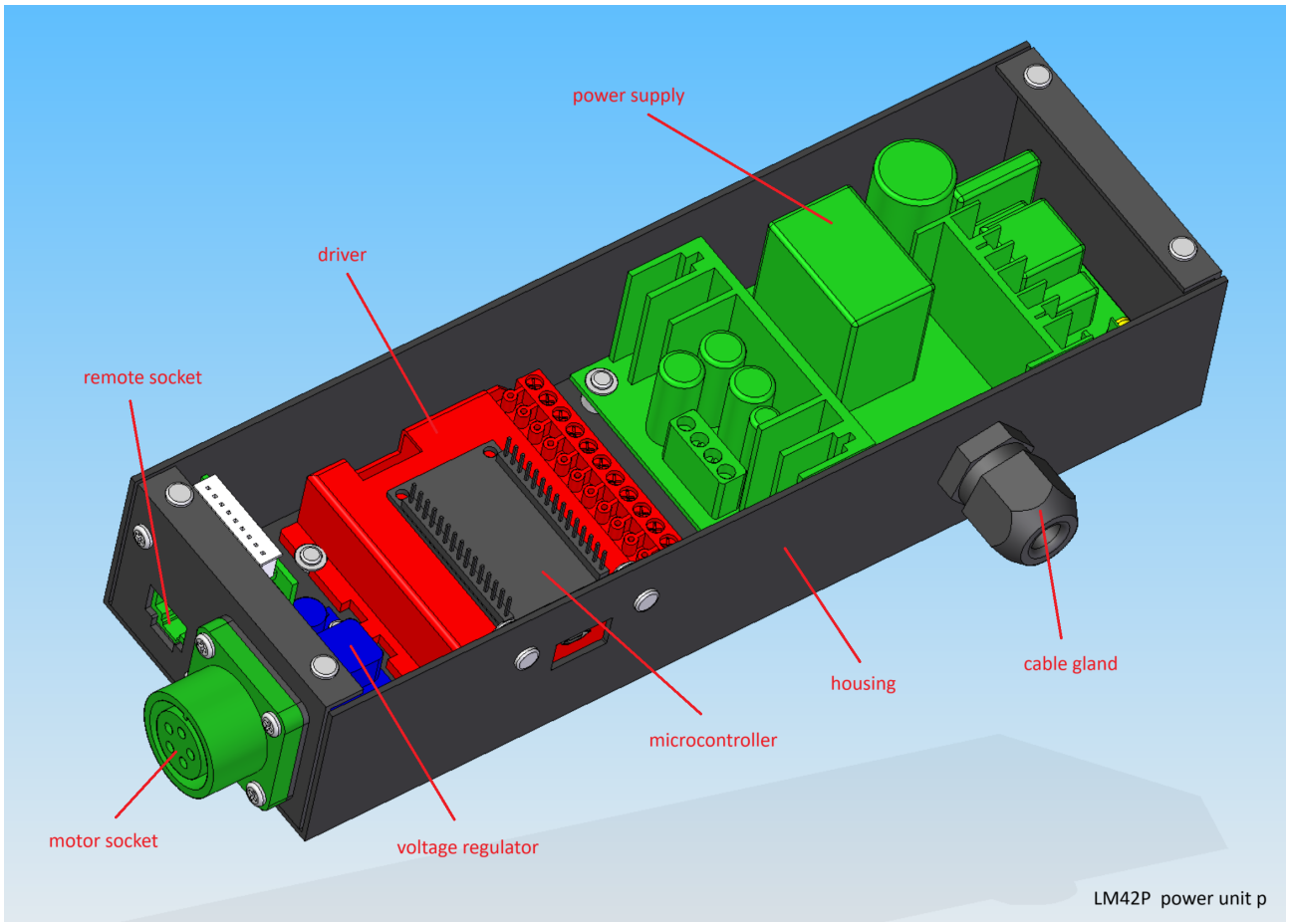


Figure 3.1: power unit p parts

3.1 Parts list

Table 3.1: Parts list of **power unit p**

Qty	Part	Description	Material
1	**housing**	78 x 47 x 240 mm	aluminium
1	**power supply**	110V/220V 36V 180W	-
1	**driver**	G201X Digital Step Drive	-
1	**microcontroller**	ESP32 30 pins	-
1	**voltage regulator**	LM2596	-
1	**motor socket**	amphenol female 5 poles	aluminium
1	**remote socket**	34 x 28 x 18 mm RJ45	-
1	**cable gland**	17 x 34 x 8 mmm	-
1	**motor plug**	amphenol male 5 poles	aluminium
1	**power supply cable**	3-core 0.5mm2 length : 2 m	-
1	**power supply plug**	depends on country 110 V or 220 V	-
1	**motor cable**	4-cores 0.5mm2 length : 1 m [1]	
1	**wire**	0.5mm2 length : 1 m	cooper
1	**wire**	0.75mm2 length : 0.50 m	cooper

[1] in case the motor is not supplied with its own

3.2 housing

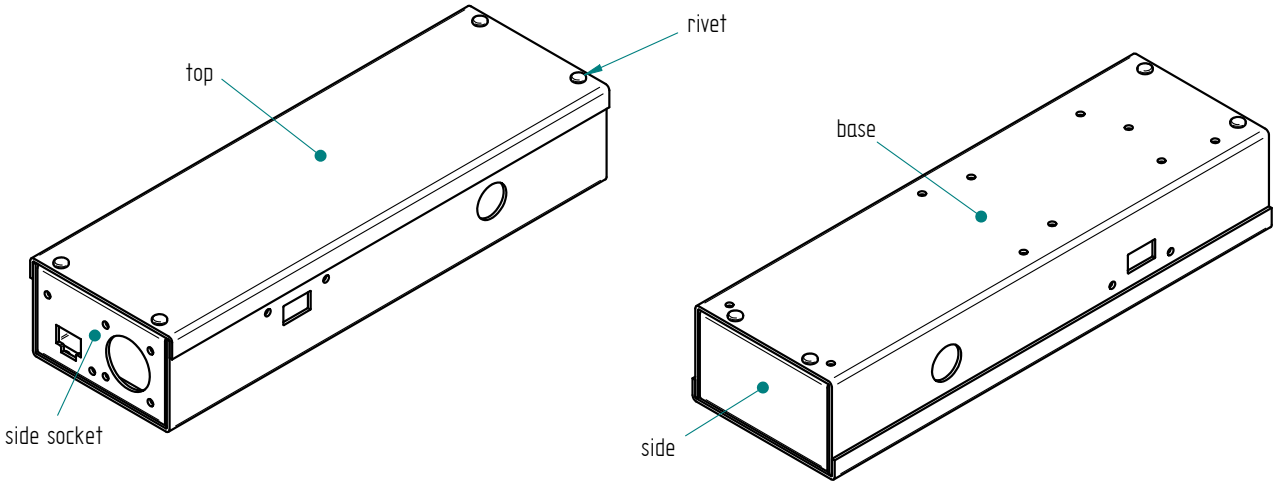


Figure 3.2: housing parts

3.2.1 Parts list

Table 3.2: Parts list of **housing**

Qty	Part	Description	Material
1	**base**	U 75 x 44 x 1.5 length : 240 mm	aluminium
1	**top**	U 78 x 10 x 1.5 length : 240 mm	aluminium
1	**side socket**	U 43 x 10 x 1.5 length : 70 mm	aluminium
1	**side**	U 43 x 10 x 1.5 length : 70 mm	aluminium
8	**rivet**	3 x 8 mm	aluminium

3.2.2 Drawing

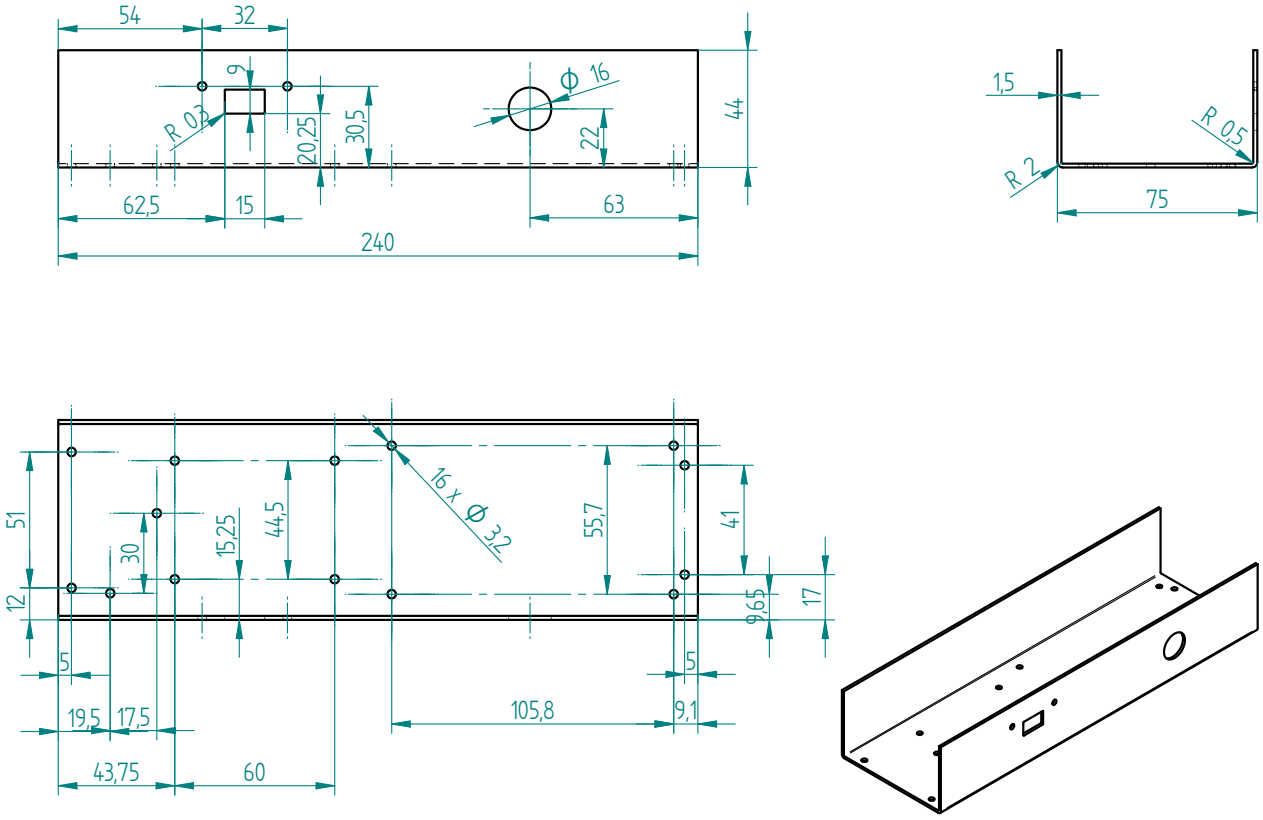


Figure 3.3: power unit p housing base drawing

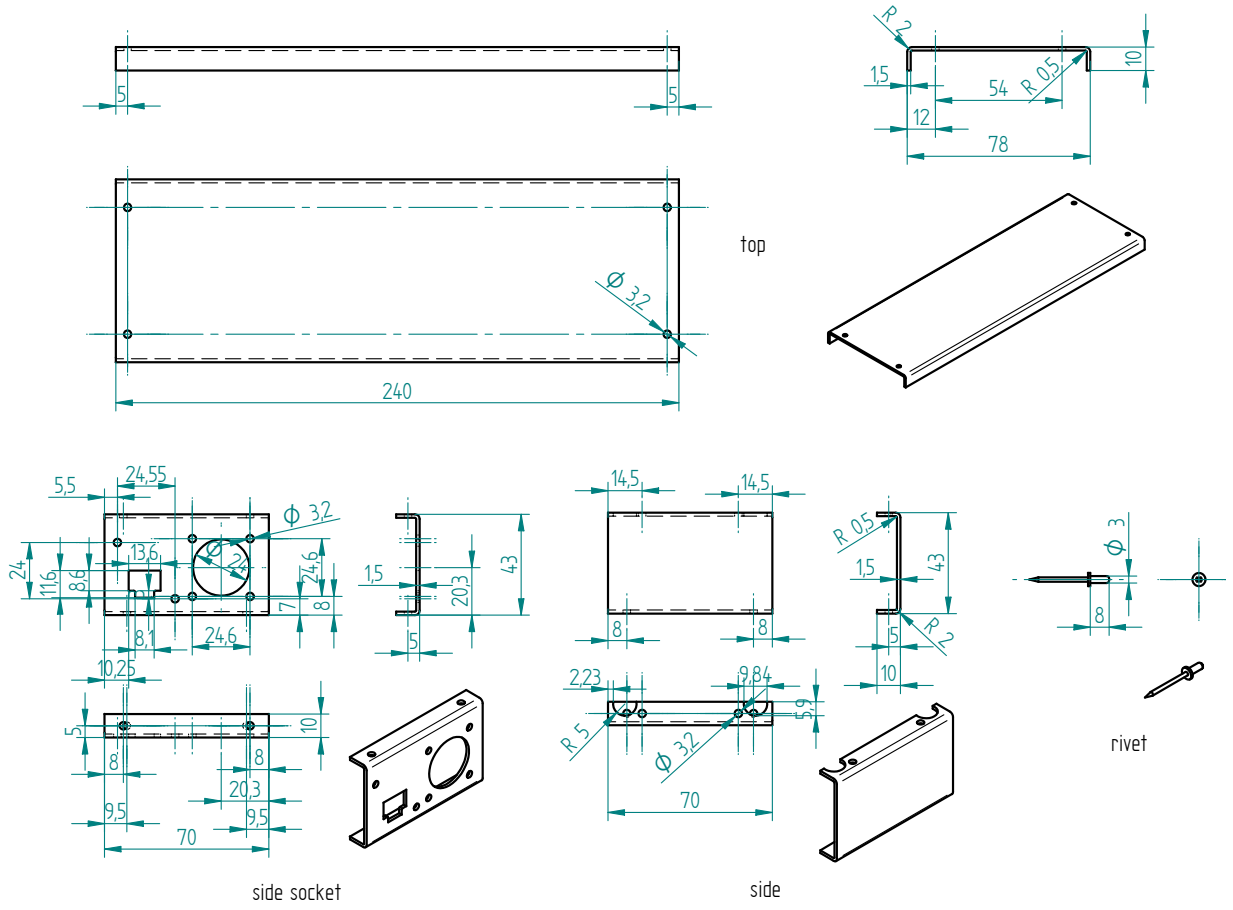


Figure 3.4: power unit p housing parts drawing

3.3 power supply

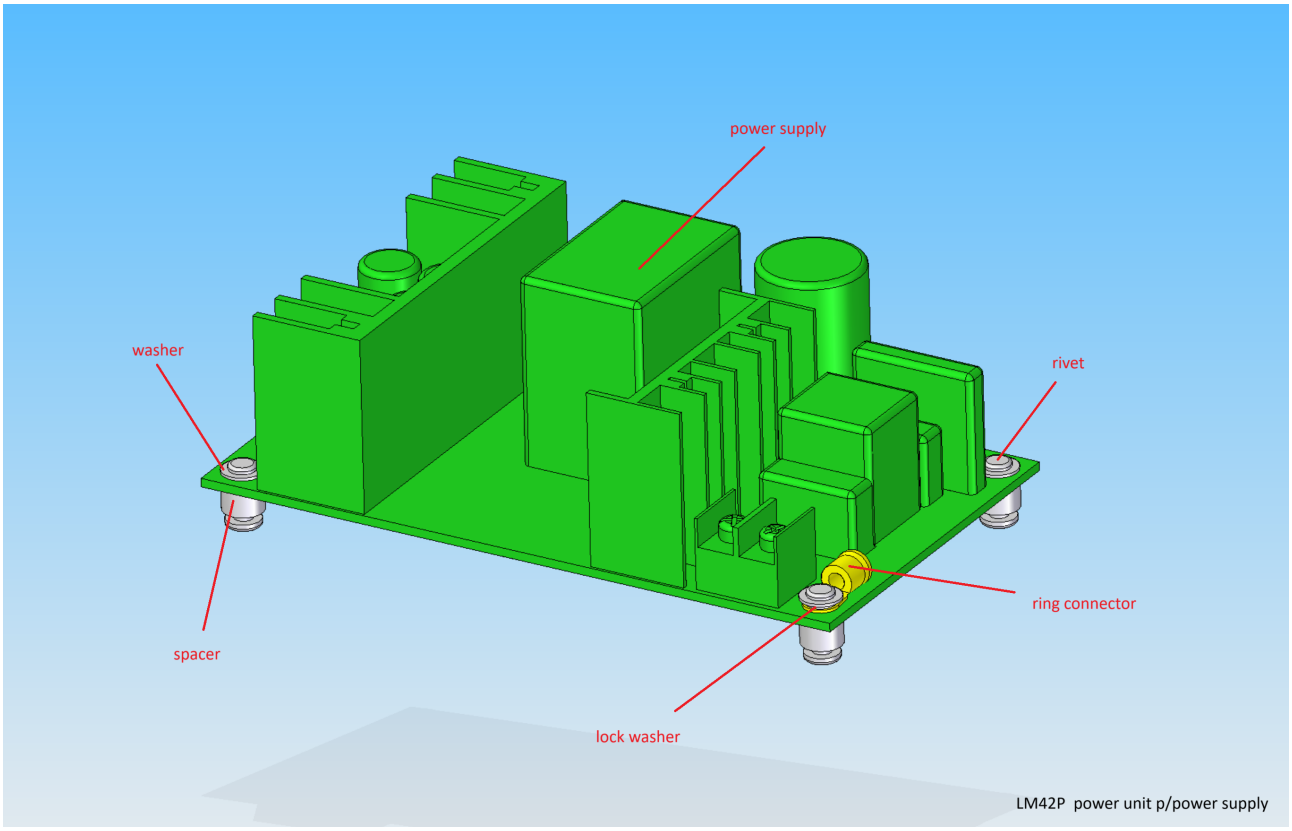


Figure 3.5: power supply parts

3.3.1 Parts list

Table 3.3: Parts list of **power supply**

Qty	Part	Description	Material
1	**power supply**	AC/DC WXDC2416 220-110/36V	-
1	**ring connector**	M3	-
1	**lock washer**	3.3 x 5.1 x 0.8	stainless steel
4	**spacer**	3.2 x 7 x 5	aluminium
4	**washer**	3.2 x 7 x 0.5	stainless steel
4	**rivet**	3 x 14 mm	aluminium

3.3.2 Drawing

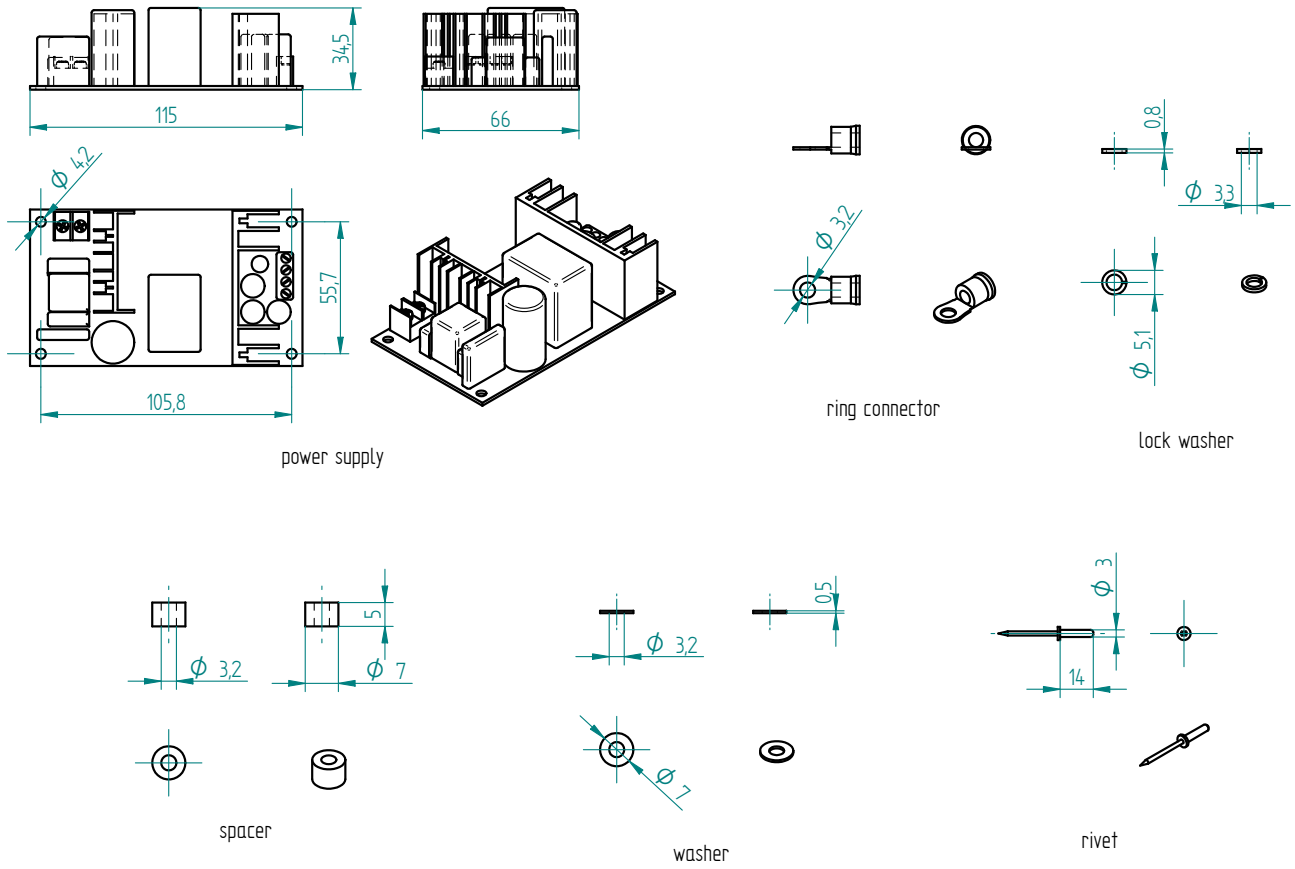


Figure 3.6: power unit p/housing/**power supply**/parts drawing

3.4 driver

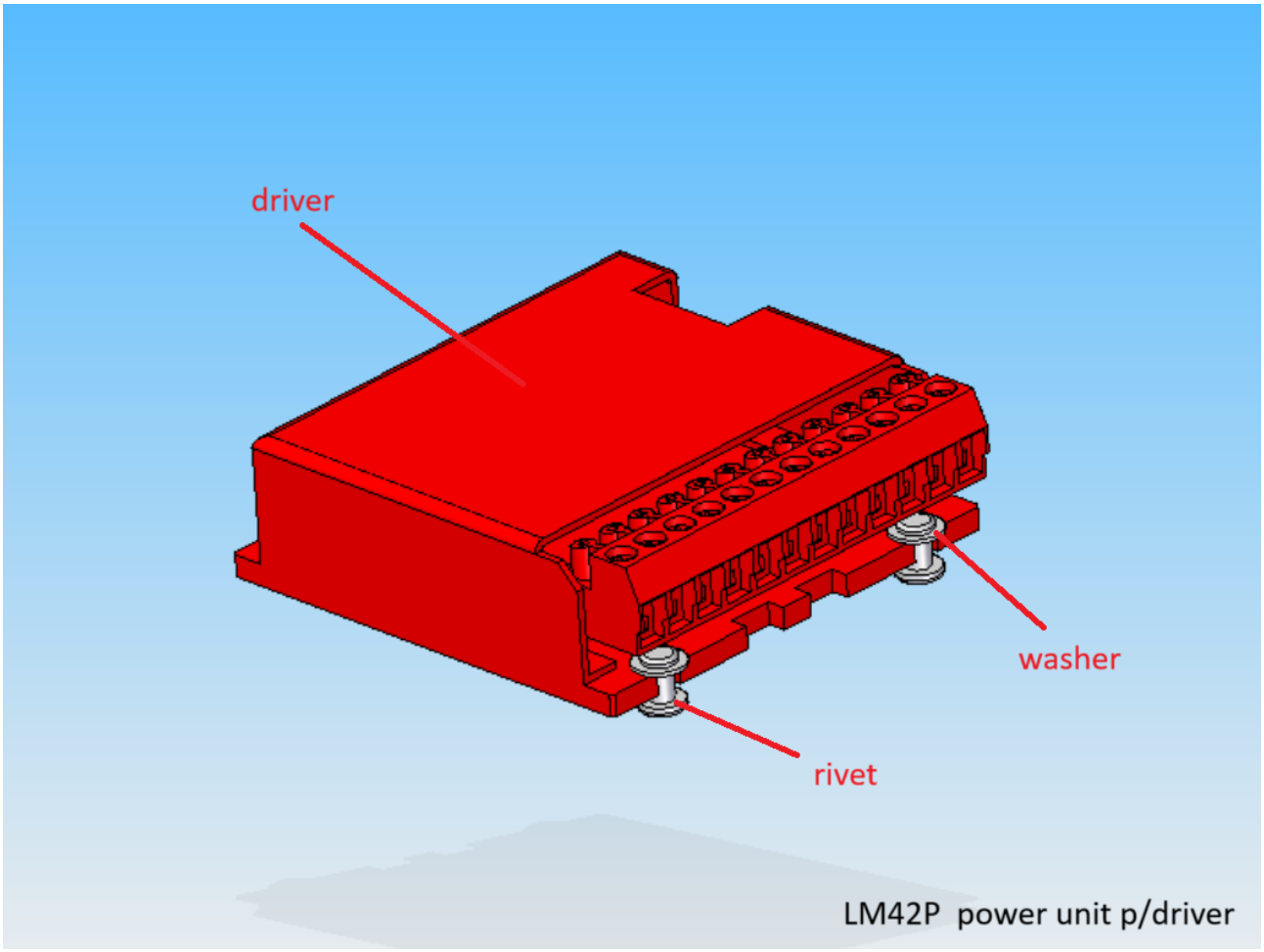


Figure 3.7: driver parts

3.4.1 Parts list

Table 3.4: Parts list of **driver**

Qty	Part	Description	Material
1	**driver**	G201X Digital Step Drive	-
4	**washer**	3.2 x 7 x 0.5	stainless steel
4	**rivet**	3 x 10 mm	aluminium

3.4.2 Drawing

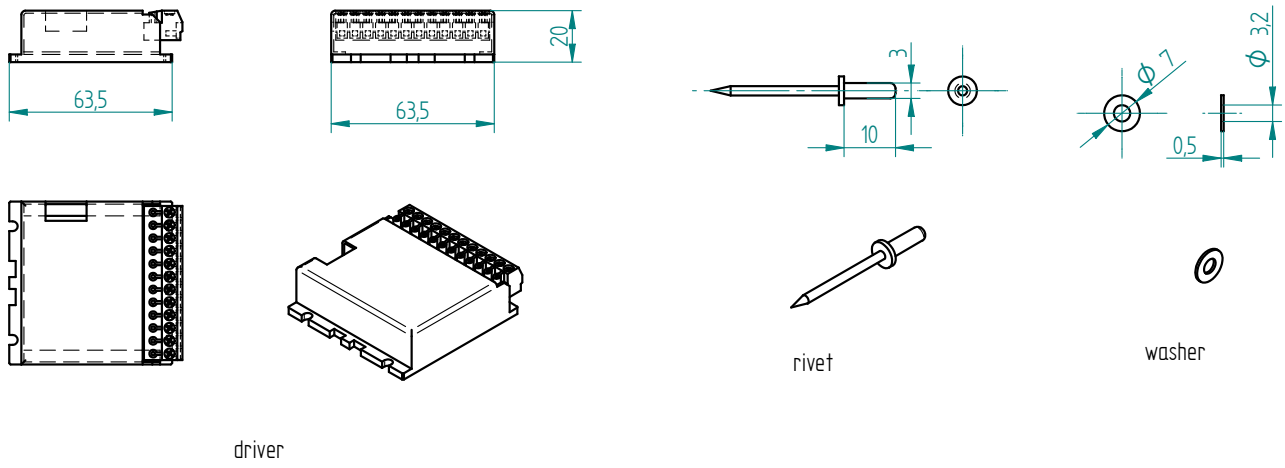


Figure 3.8: power unit p/housing/**driver** parts drawing

3.5 microcontroller

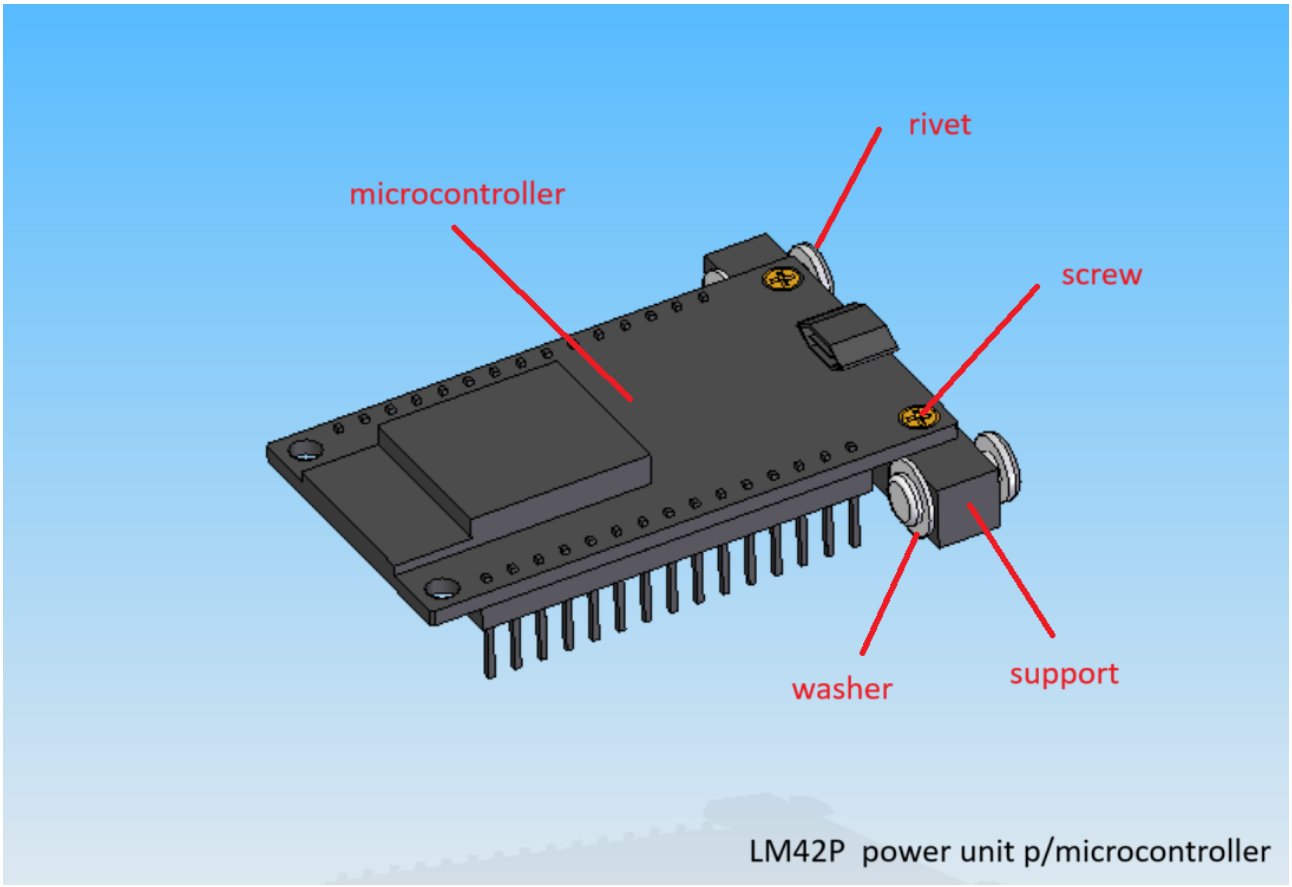


Figure 3.9: microcontroller parts

3.5.1 Parts list

Table 3.5: Parts list of **microcontroller**

Qty	Part	Description	Material
1	**microcontroller**	ESP32 30 pins	-
1	**support**	3D printed	PLA
2	**screw**	2 x 8	brass
2	**washer**	3.2 x 7 x 0.5	stainless steel
2	**rivet**	3 x 12 mm	aluminium

3.5.2 Drawing

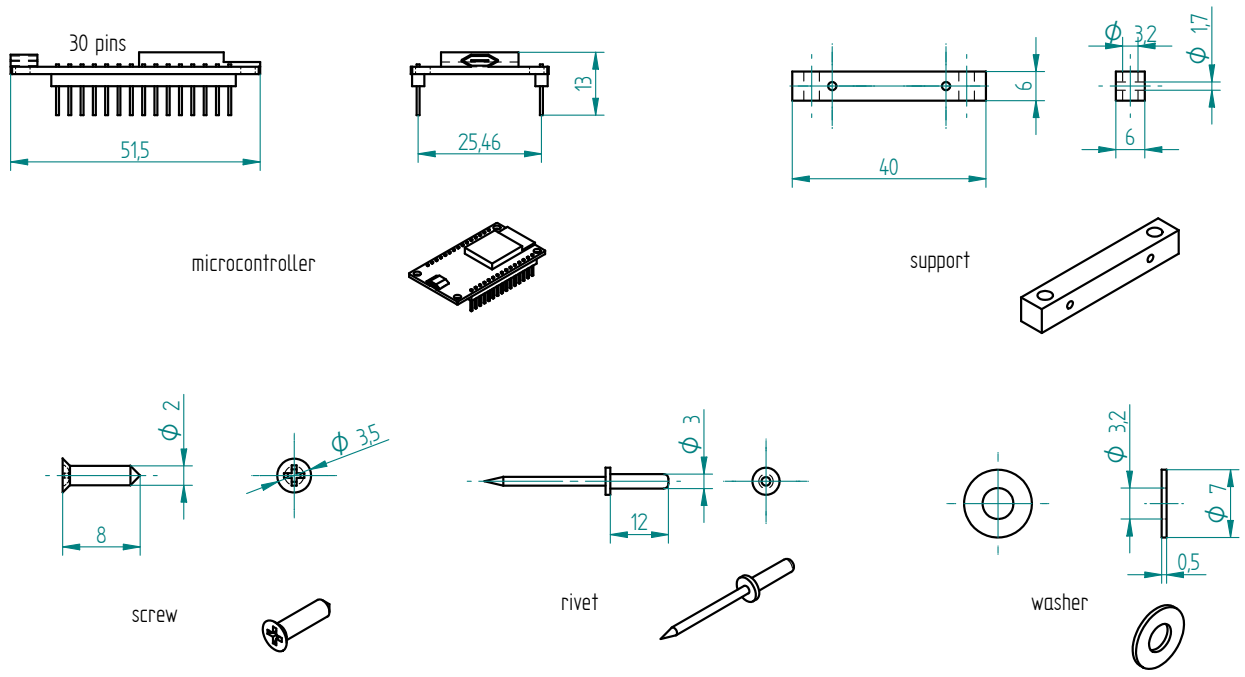


Figure 3.10: power unit p/housing/**microcontroller** parts drawing

3.6 voltage regulator

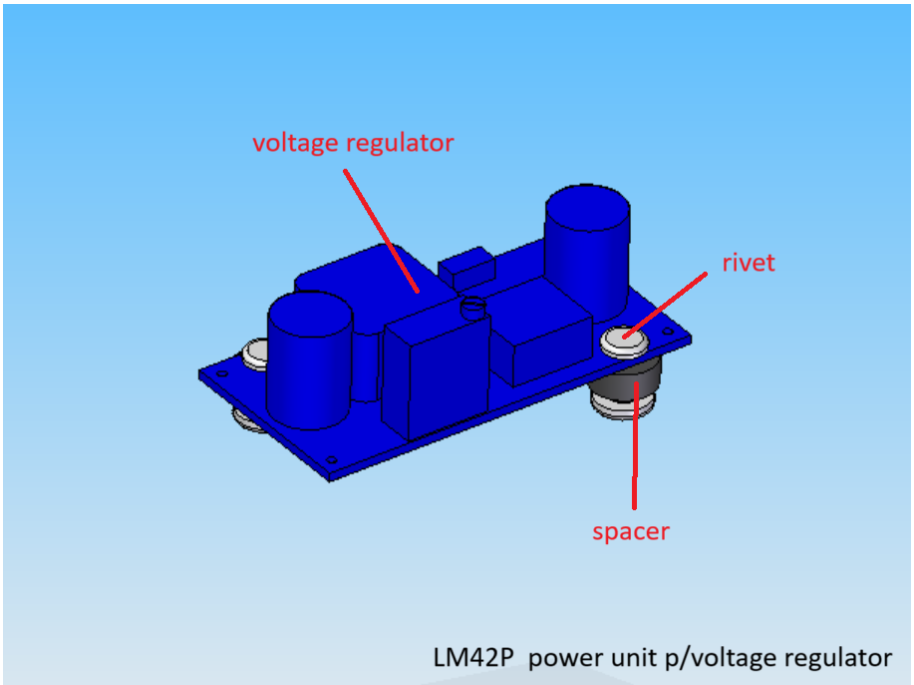


Figure 3.11: voltage regulator parts

3.6.1 Parts list

Table 3.6: Parts list of **voltage regulator**

Qty	Part	Description	Material
1	**voltage regulator**	LM2596	-
2	**spacer**	3.2 x 7 x 3	nylon
2	**rivet**	3 x 8 mm	aluminium

3.6.2 Drawing

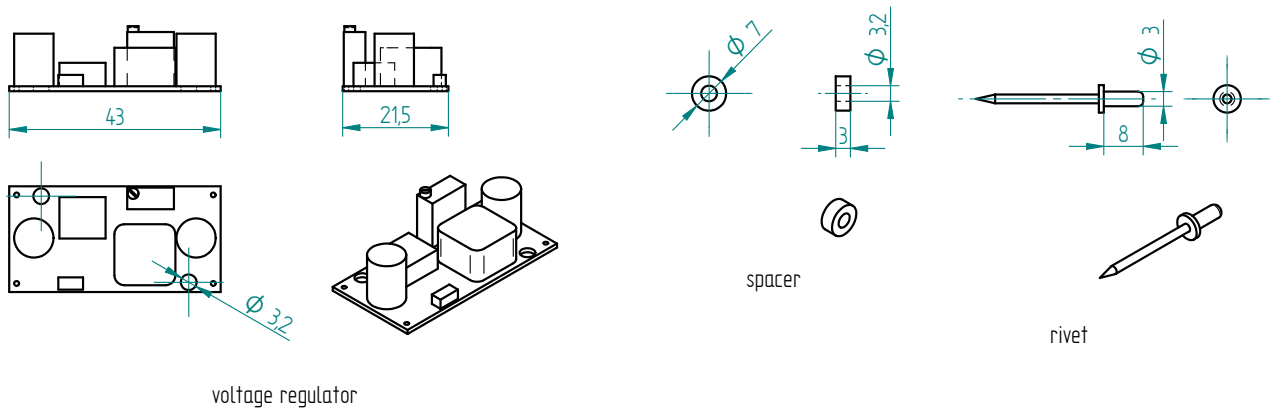


Figure 3.12: power unit p/housing/**voltage regulator** parts drawing

3.7 motor socket

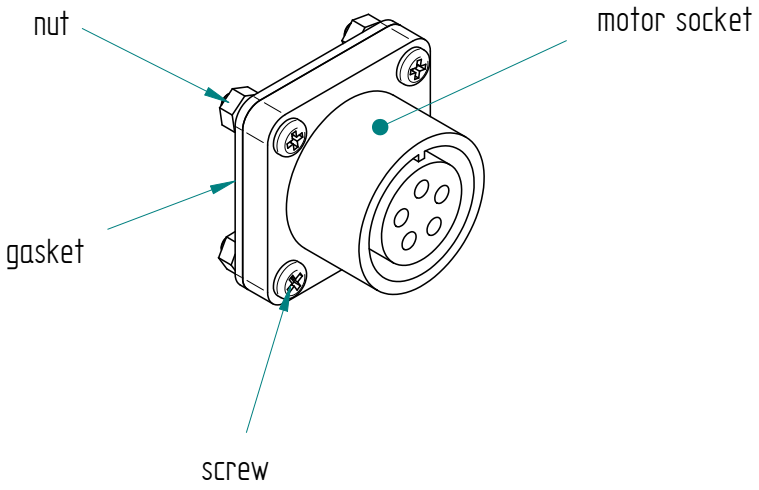


Figure 3.13: motor socket parts

3.7.1 Parts list

Table 3.7: Parts list of **motor socket**

Qty	Part	Description	Material
1	**motor socket**	amphenol female 5 poles	aluminium
1	**gasket**	32.5 x 32.5 x 1.5	rubber
4	**screw**	M3 x 12 mm	stainless steel
4	**nut**	M3	stainless steel

3.7.2 Drawing

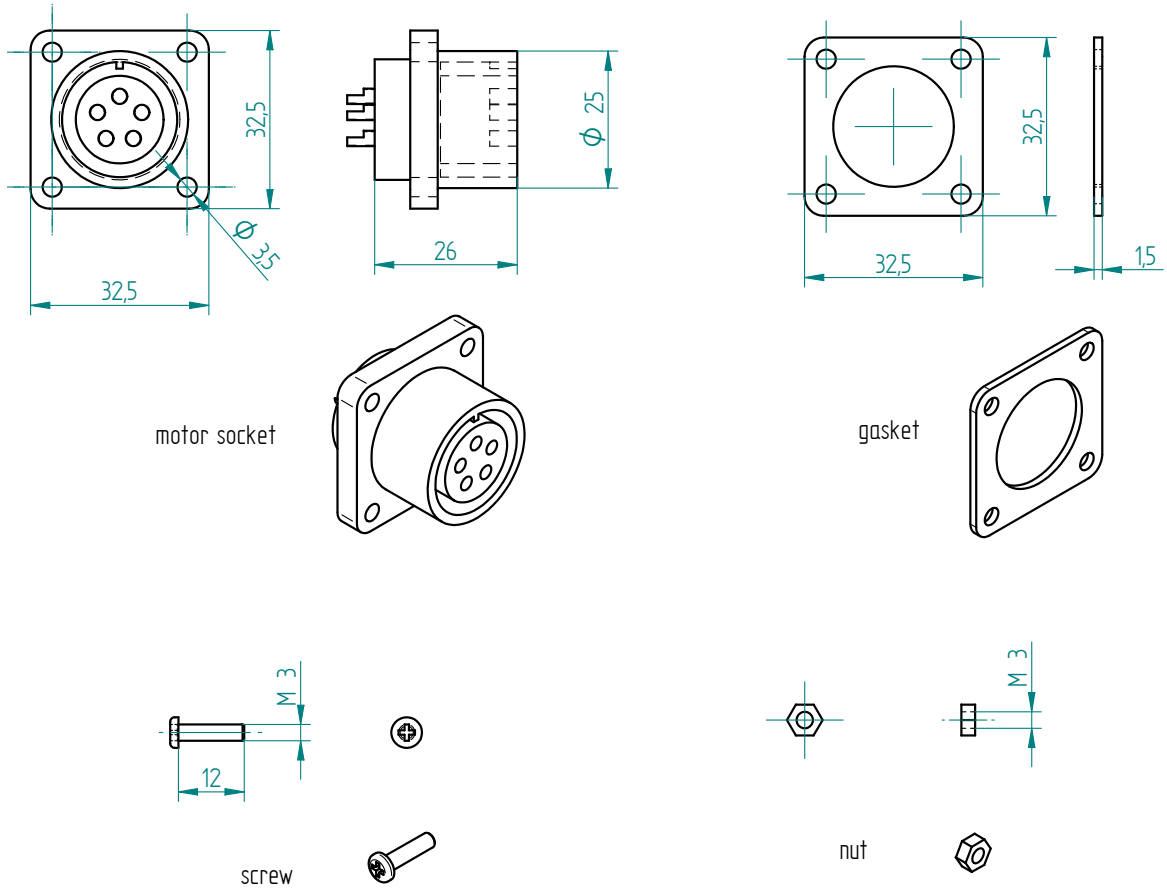


Figure 3.14: power unit p/housing/**motor socket** parts drawing

3.8 remote socket

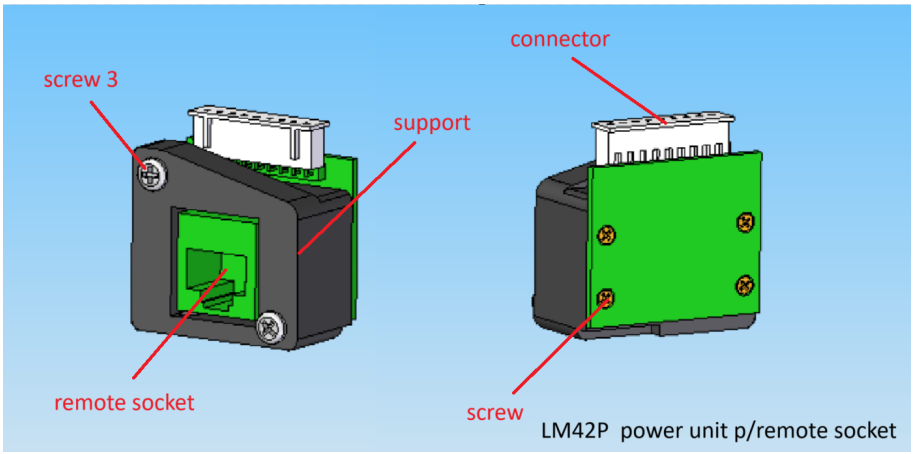


Figure 3.15: remote socket parts

3.8.1 Parts list

Table 3.8: Parts list of **remote socket**

Qty	Part	Description	Material
1	**remote socket**	34 x 28 x 18 RJ45	-
1	**support**	3D printed	PLA
4	**screw**	2 x 10 mm	brass
2	**screw 3**	2.9 x 10 mm	stainless steel
2	**connector**	24.3 x 7 x 4 mmm 9 poles	-

3.8.2 Drawing

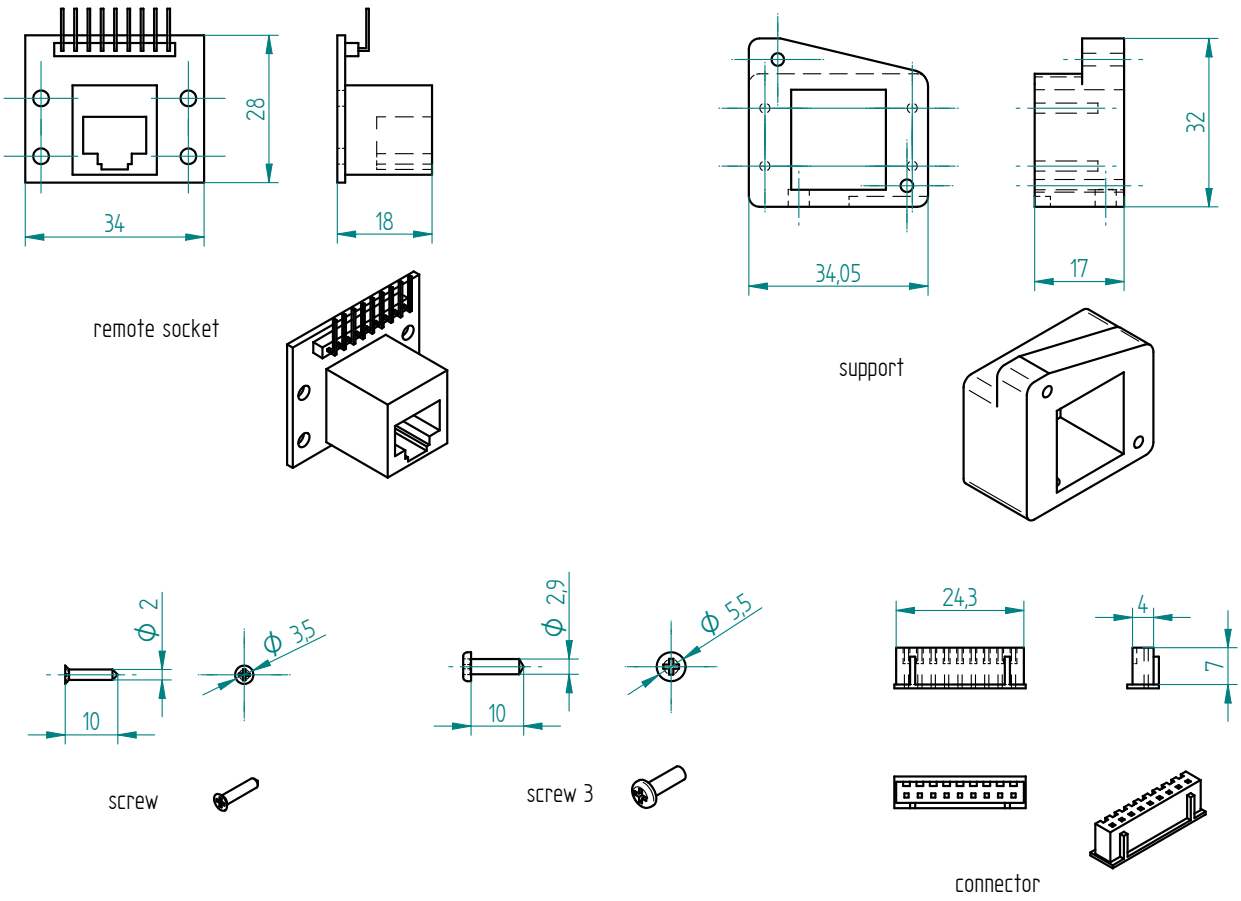


Figure 3.16: power unit p/housing/**remote socket** parts drawing

3.9 cable gland

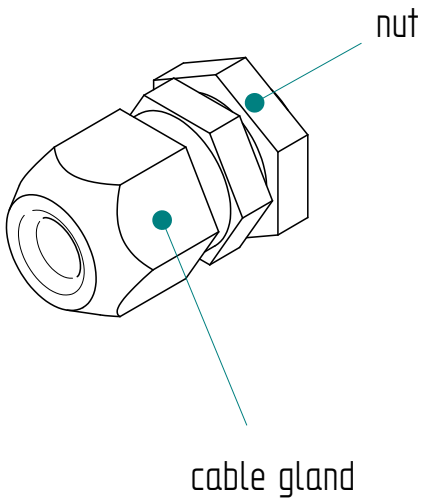


Figure 3.17: cable gland parts

3.9.1 Parts list

Table 3.9: Parts list of **cable gland**

Qty	Part	Description	Material
1	**cable gland**	17 x 34 x 8 mm	nylon
1	**nut**	17 x 5 mm	nylon

3.9.2 Drawing

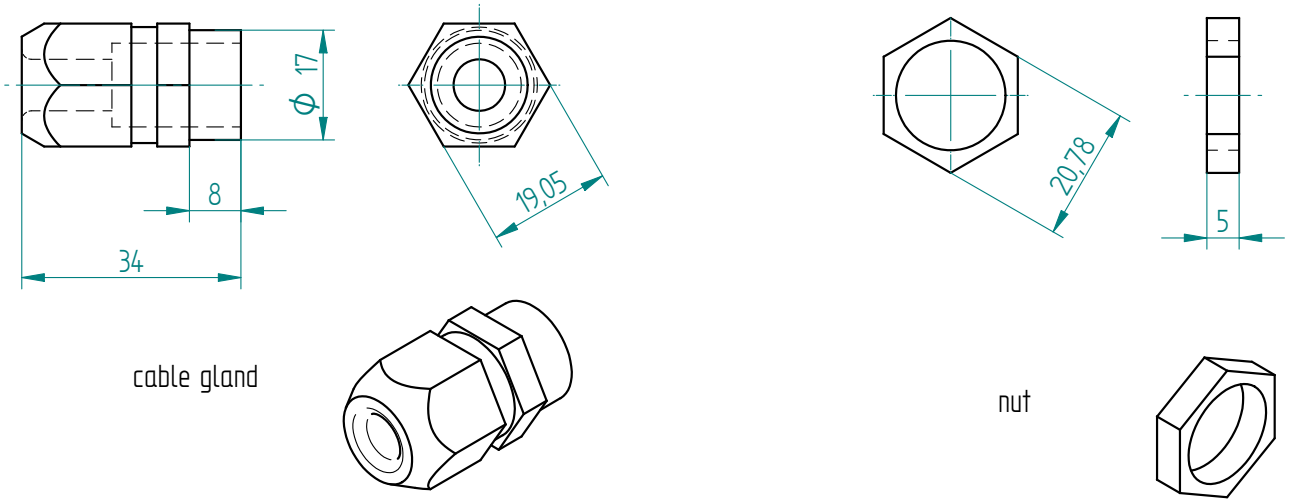


Figure 3.18: power unit p/housing/**cable gland** parts drawing

3.10 motor plug

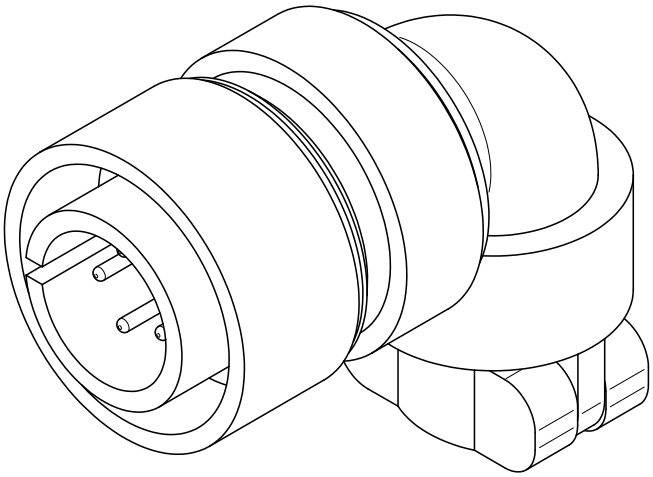


Figure 3.19: motor plug

3.10.1 Parts list

Table 3.10: Parts list of **motor plug**

Qty	Part	Description	Material
1	**motor plug**	amphenol male 5 poles	aluminium

3.10.2 Drawing

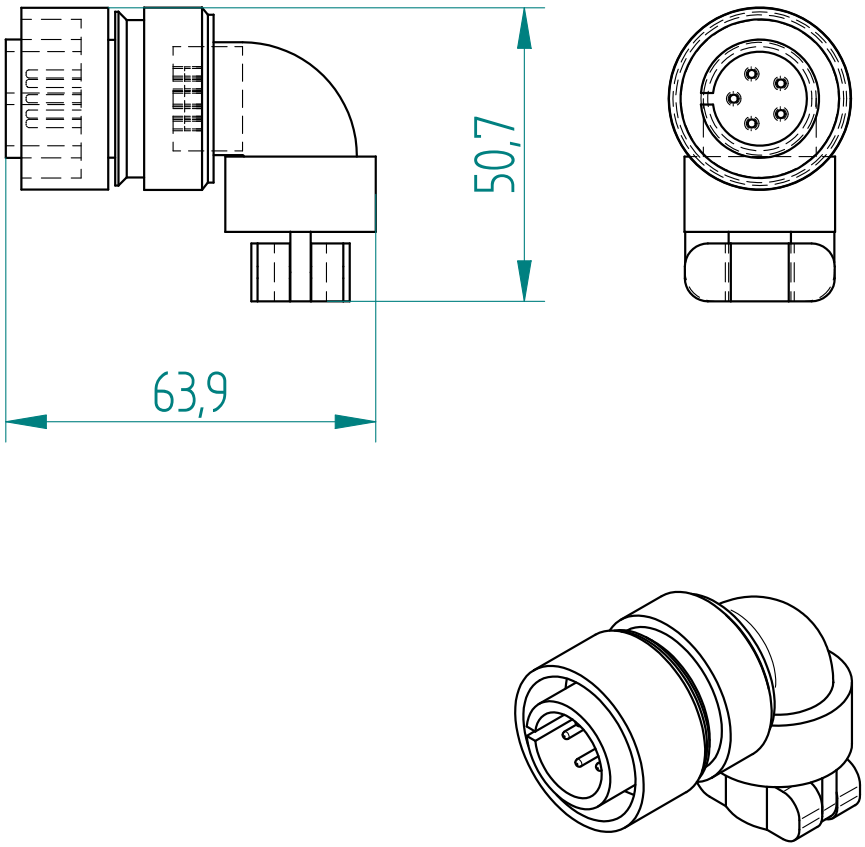


Figure 3.20: power unit p/housing/**motor plug** drawing

3.11 Wiring

3.11.1 Wiring diagram

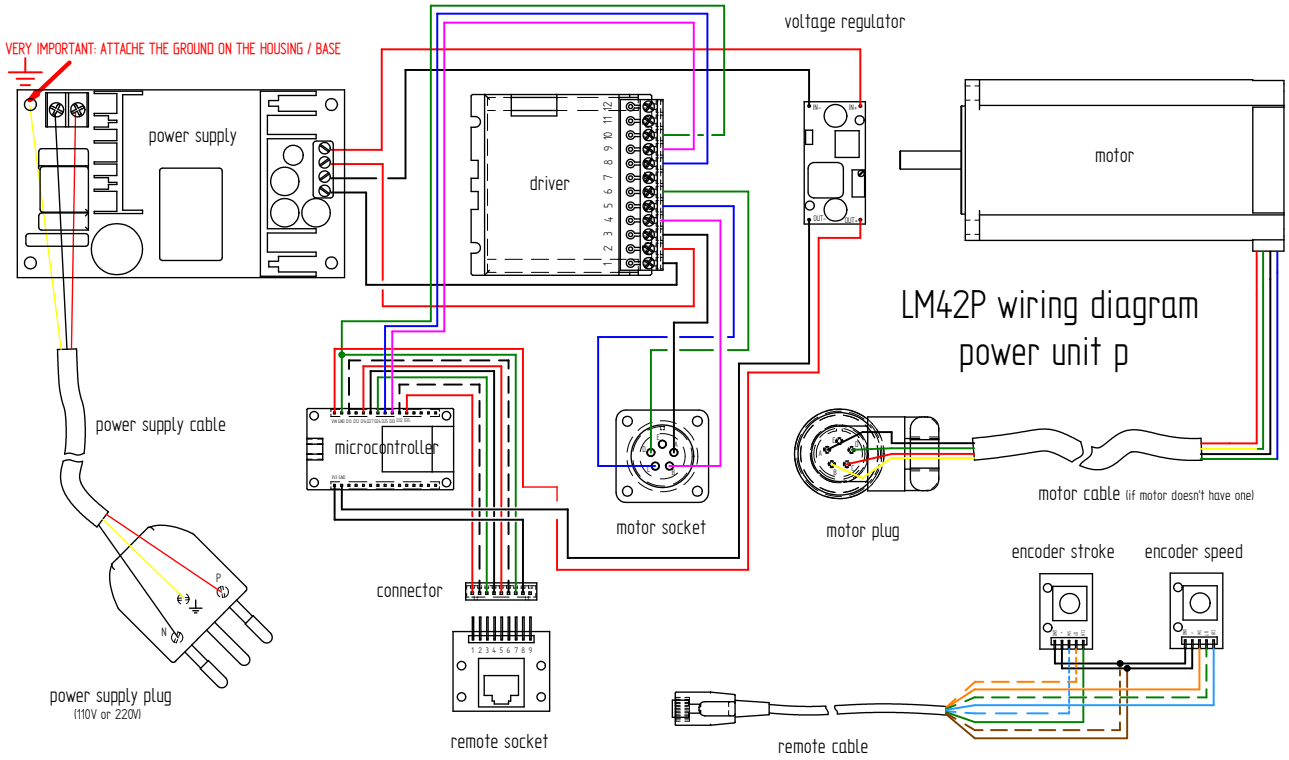


Figure 3.21: Wiring diagram

3.11.2 Parts list

Table 3.11: Parts list for wiring **power unit p**

Qty	Part	Description	Material
1	**power supply cable**	3 poles 0.75mm2 length : 2 m	-
1	**power supply plug**	depends on country 110 V or 220 V	-
1	**motor cable**	4 poles 0.5mm2 length : 1 m[2]	
1	**wire**	0.5mm2 length : 1 m	cooper

continued on next page ...

[2]If the motor is not supplied with its own cable, refer to Appendix C, page 177, for instructions on how to attach it.

... continued

Qty	Part	Description	Material
1	**wire**	0.75mm2 length : 0.50 m	cooper

Required Tools and Components

- 1x wire cutter ;
- 1x wire stripper ;
- 1x terminal crimping tool ;
- 1x multimeter ;
- 1x soldering iron ;
- 1x solder ;
- 1x gauge ;
- 1x screwdriver 0 ;
- 1x rivet gun ;
- 1x water pump pliers ;
- 1x electrical tape.

3.11.3 Wiring Instructions

The lengths and cross-sectional areas of the wires are listed in table 3.12, page 122.

1. File the bottom of the **base** (only the part where the red framed hole is) so that the grounding contact faces well. This operation is not necessary if you are using non anodized sheets (anodized surfaces are none-conductive). See Figure 3.22, page 120.

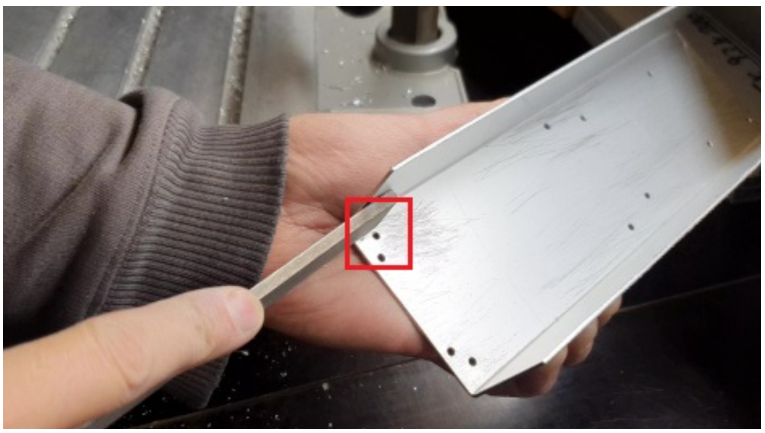


Figure 3.22: Make the housing base conductive

2. Strip the **power supply cable** 3 cores at 10cm.
3. Tighten the **ring connector** on the ground wire (yellow).
4. Fix the **cable gland** to the **base**.
5. Tighten **cable gland**.
6. Control the **power supply** : control the voltage of the output of the **power supply** with a voltmeter. It should be 36V.
7. Install the **power supply** in the **base**, ensuring that the ground connection is correctly made (see Figure 3.23, page 120).

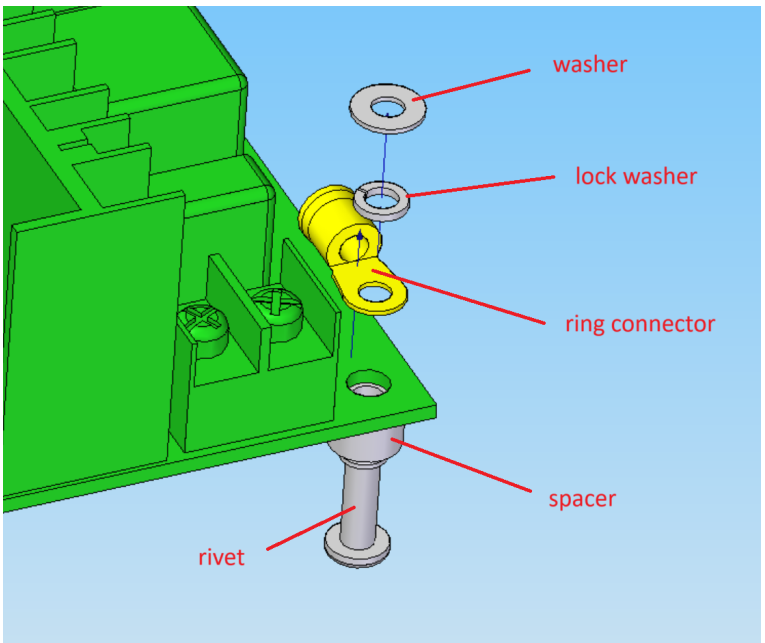


Figure 3.23: Connect the power supply ground to the base and power supply cable ground

8. Connect and tighten the **phase** and **neutral** wires to the 36V "IN" terminals of the **power supply**.

9. Connect the **power supply plug** to the **power supply cable**.
10. Use a multimeter (in resistance mode) to verify that the ground of the **power supply plug** is properly connected to the **base**.
11. Solder the four wires to the corresponding pins on the **voltage regulator** :
    - Connect the wire to IN+ (input positive).
    - Connect the wire to IN- (input negative).
    - Connect the wire to OUT+ (output positive).
    - Connect the wire to OUT- (output negative).
12. Install the **voltage regualator** in the **base**.
13. Adjust **voltage regulator** voltage :
    (a) Connect the **voltage regulator** IN to the **power supply** OUT ;
    (b) Connect the voltmeter to **voltage regulator** OUT
14. Solder the four wires to the **motor socket**.
15. Install all other components in the **base**.
16. Wire them properly (see Terminals Connection and Wires details in Table 3.12, page 122 and Wiring diagram 3.21, 118).
17. If the motor does not already have a cable installed, solder four wires to the motor. See **Appendix: Attach the motor cable** C, page 177, for instructions on how to attach it.[3]
18. Wire the **motor plug** :
    (a) Strip the outer cable sheath over a length of 3 cm.
    (b) Strip the four inner wires and solder them as required.
    (c) At 5 cm from the edge, wrap 10 layers of electrical tape around the cable.
    (d) Soldered the four wires as follows [4] :
        - red → C ;
        - green → B ;
        - black → A ;
        - blue → D.
    (e) Assemble the plug and tighten the flange.
    (f) Wire the **remote-d**.

[3] It is much easier if you can get a motor with the cable already wired.

[4] "Actually, this is not the same as shown in the ESP schematic. I connected the M2 according to the table, but next time I need to follow the ESP schematic and check whether the red and green sides of the machine are the same."

3.11.4 Terminals Connections and Wires details

Table 3.12: Connections and wire details

Connections	wire length [cm]	wire section [mm2]
D35_microcontroller - 1_connector	9	0.25
D32_microcontroller - 2_connector	9	0.25
D33_microcontroller - 9_driver	9	0.25
D25_microcontroller - 8_driver	9	0.25
D26_microcontroller - 3_connector	9	0.25
D27_microcontroller - 4_connector	9	0.25
D14_microcontroller - 5_connector	9	0.25
D13_microcontroller - 6_connector	9	0.25
10_driver - 7_connector	15 (don't cut)	0.25
10_driver - GND_microcontroller	9[5]	0.5
3_driver - A_motor socket	15	0.75
4_driver - B_motor socket	15	0.75
5_driver - C_motor socket	15	0.75
6_driver - D_motor socket	15	0.75
8_connector - VIN_microcontroller	?	0.25
OUT-_voltage regulator - GND_microcontroller	7	0.5
OUT+_voltage regulator - VIN_microcontroller	12	0.5
IN+_voltage regulator - OUT+_power supply	16	0.5
IN-_voltage regulator - OUT-_power supply	15	0.5

[5]Wired according to precedent and tightly bundled within the 10_driver

3.12 Firmware

After all components have been installed and wired inside the **housing**, it is time to upload the firmware to the **microcontroller**.

3.12.1 m1

The firmware source code for machine **m1** is located in the `firmware` directory. A portion of the firmware code is shown below.

To upload the firmware, please follow the steps described in Appendix B (page 175).

```
//speed rotary encoder
#define ROTARY_ENCODER_A_PIN 27 //CLK
#define ROTARY_ENCODER_B_PIN 26 //DT
#define ROTARY_ENCODER_BUTTON_PIN 32 //SW
#define ROTARY_ENCODER_STEPS 4
#define ROTARY_ENCODER_ACCELERATION 2000 //30000 3000
AiEsp32RotaryEncoder rotaryEncoder = AiEsp32RotaryEncoder(
   ROTARY_ENCODER_A_PIN, ROTARY_ENCODER_B_PIN,
   ROTARY_ENCODER_BUTTON_PIN, -1, ROTARY_ENCODER_STEPS);

// stroke rotary encoder
#define ROTARY_ENCODER2_A_PIN 13 //CLK
#define ROTARY_ENCODER2_B_PIN 35 //DT
#define ROTARY_ENCODER2_BUTTON_PIN 14 //SW
#define ROTARY_ENCODER2_STEPS 4
#define ROTARY_ENCODER2_ACCELERATION 7000
AiEsp32RotaryEncoder rotaryEncoder2 = AiEsp32RotaryEncoder(
   ROTARY_ENCODER2_A_PIN, ROTARY_ENCODER2_B_PIN,
   ROTARY_ENCODER2_BUTTON_PIN, -1, ROTARY_ENCODER2_STEPS);

void IRAM_ATTR readEncoderISR()
{
  rotaryEncoder.readEncoder_ISR();
  rotaryEncoder2.readEncoder_ISR();
}

// IO pin assignments
const int MOTOR_STEP_PIN = 33;
const int MOTOR_DIRECTION_PIN = 25;

// Speed and stroke settings
const int MIN_SPEED = 2000; //set min speed in us/step
const int MAX_SPEED = 10; // no diff 5 and 20 5 10 15 25 45 speed/
   accelration for 1kg toy: 45/320000
                          // higher the acceleration and lower value
                             of speed can be set to be
                          // more speedy
const int MIN_STROKE = 10; // 10 vibro_stroke = 10
const int MAX_STROKE = 4800; //4850 4650 4600 4500 4000

```

```
// Motor acceleration
int MOTOR_ACCELERATION = 320000; // 640000 for small toy 850000 decroche 640000 320000; // speed/acceleration for 1kg toy: 45/320000

FastAccelStepperEngine engine = FastAccelStepperEngine();
FastAccelStepper *stepper = NULL;

long target = 0; // it's the target
int previousDirection = 1;
bool stopped = true; //machine stopped
unsigned long lastButtonPress = 0; // avoid rebounce when button is pressed
bool green = false; // green side of the machine is used
bool red = false; // red side of the machine is used
const int GAP = 50; // gap between the end of machine and mobile part ;

void setup() {
  Serial.begin(115200);
  pinMode(ROTARY_ENCODER_A_PIN, INPUT_PULLUP);
  pinMode(ROTARY_ENCODER_B_PIN, INPUT_PULLUP);

  pinMode(ROTARY_ENCODER2_A_PIN, INPUT_PULLUP);
  pinMode(ROTARY_ENCODER2_B_PIN, INPUT_PULLUP);
```

Listing 3.1: Partial code: firmware.ino

3.12.2 m2

The firmware source code for machine **m2** is located in the `firmware` directory. A portion of the firmware code is shown below.

To upload the firmware, please follow the steps described in Appendix B (page 175).

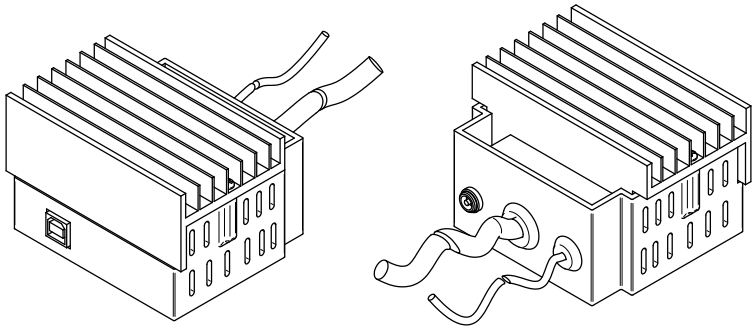
```
//speed rotary encoder
#define ROTARY_ENCODER_A_PIN 27 //CLK
#define ROTARY_ENCODER_B_PIN 26 //DT
#define ROTARY_ENCODER_BUTTON_PIN 32 //SW
#define ROTARY_ENCODER_STEPS 4
#define ROTARY_ENCODER_ACCELERATION 2000 //30000 3000
AiEsp32RotaryEncoder rotaryEncoder = AiEsp32RotaryEncoder(ROTARY_ENCODER_A_PIN, ROTARY_ENCODER_B_PIN, ROTARY_ENCODER_BUTTON_PIN, -1, ROTARY_ENCODER_STEPS);

// stroke rotary encoder
#define ROTARY_ENCODER2_A_PIN 13 //CLK
#define ROTARY_ENCODER2_B_PIN 35 //DT
#define ROTARY_ENCODER2_BUTTON_PIN 14 //SW
#define ROTARY_ENCODER2_STEPS 4
#define ROTARY_ENCODER2_ACCELERATION 7000
```

```
15 AiEsp32RotaryEncoder rotaryEncoder2 = AiEsp32RotaryEncoder(
       ROTARY_ENCODER2_A_PIN, ROTARY_ENCODER2_B_PIN,
       ROTARY_ENCODER2_BUTTON_PIN, -1, ROTARY_ENCODER2_STEPS);
16
17 void IRAM_ATTR readEncoderISR()
18 {
19   rotaryEncoder.readEncoder_ISR();
20   rotaryEncoder2.readEncoder_ISR();
21 }
22
23 // IO pin assignments
24 const int MOTOR_STEP_PIN = 33;
25 const int MOTOR_DIRECTION_PIN = 25;
26
27 // Speed and stroke settings
28 const int MIN_SPEED = 2000; //set min speed in us/step
29 const int MAX_SPEED = 10; // no diff 5 and 20 5 10 15 25 45 speed/
       accelration for 1kg toy: 45/320000
30                           // higher the acceleration and lower value
                                of speed can be set to be
31                           // more speedy
32 const int MIN_STROKE = 10; // 10 vibro_stroke = 10
33 const int MAX_STROKE = 4800; //4850 4650 4600 4500 4000
34
35 // Motor acceleration
36 int MOTOR_ACCELERATION = 320000; // 640000 for small toy 850000
       decroche 640000 320000; // speed/acceleration for 1kg toy:
       45/320000
37
38 FastAccelStepperEngine engine = FastAccelStepperEngine();
39 FastAccelStepper *stepper = NULL;
40
41 long target = 0; // it's the target
42 int previousDirection = 1;
43 bool stopped = true; //machine stopped
44 unsigned long lastButtonPress = 0; // avoid rebounce when button is
       pressed
45 bool green = false; // green side of the machine is used
46 bool red = false; // red side of the machine is used
47 const int GAP = 50; // gap between the end of machine and mobile part
       ;
48
49 void setup() {
50   Serial.begin(115200);
51   pinMode(ROTARY_ENCODER_A_PIN, INPUT_PULLUP);
```

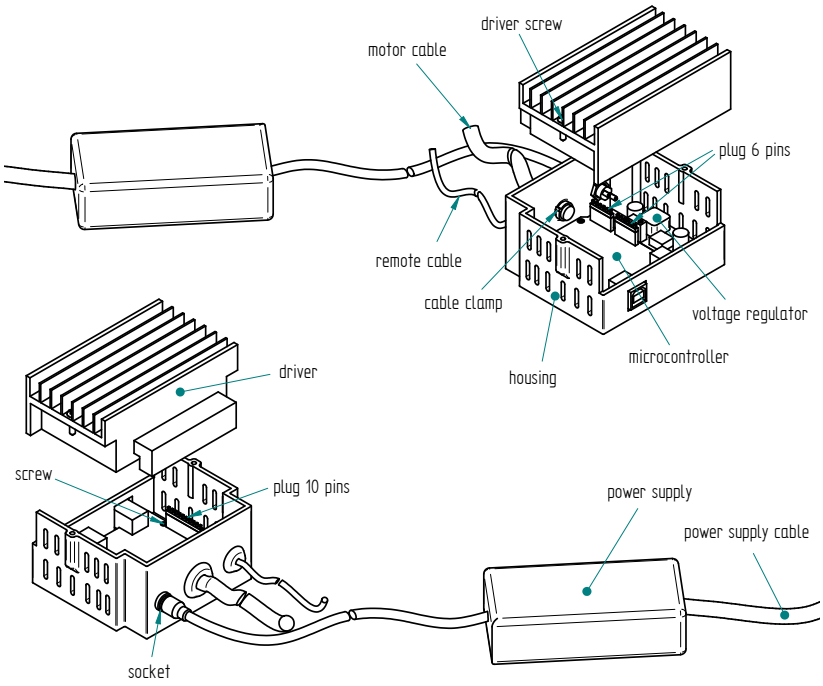
Listing 3.2: Partial code: firmware.ino

Chapter 4

power unit a



This chapter explains how to build the **power unit a**.



4.1 Parts list

Table 4.1: Parts list of **power unit a**

Qty	Part	Description	Material
1	**housing**	3D printed	PLA
1	**driver**	TB6600	-
1	**microcontroller**	Arduino Uno	-
1	**plug 10 pins**	delivered with Arduino Uno	-
2	**plug 6 pins**	delivered with Arduino Uno	-
1	**voltage regulator**	LM2596	-
1	**socket**	2.1/5.5	-
1	**nut**	M8	-
6	**screw**	M2 x 5	brass
2	**driver screw**	2.9 x 13	stainless steel
1	**motor cable clamp**	2.5	nylon (cable tie)
1	**remote cable clamp**	2.5	nylon (cable tie)
1	**power supply**	110-220V/24V 6A	-
1	**power supply cable**	plug depends on country 110 V or 220 V	-

4.2 Drawing

See Figure 4.1, page 129.

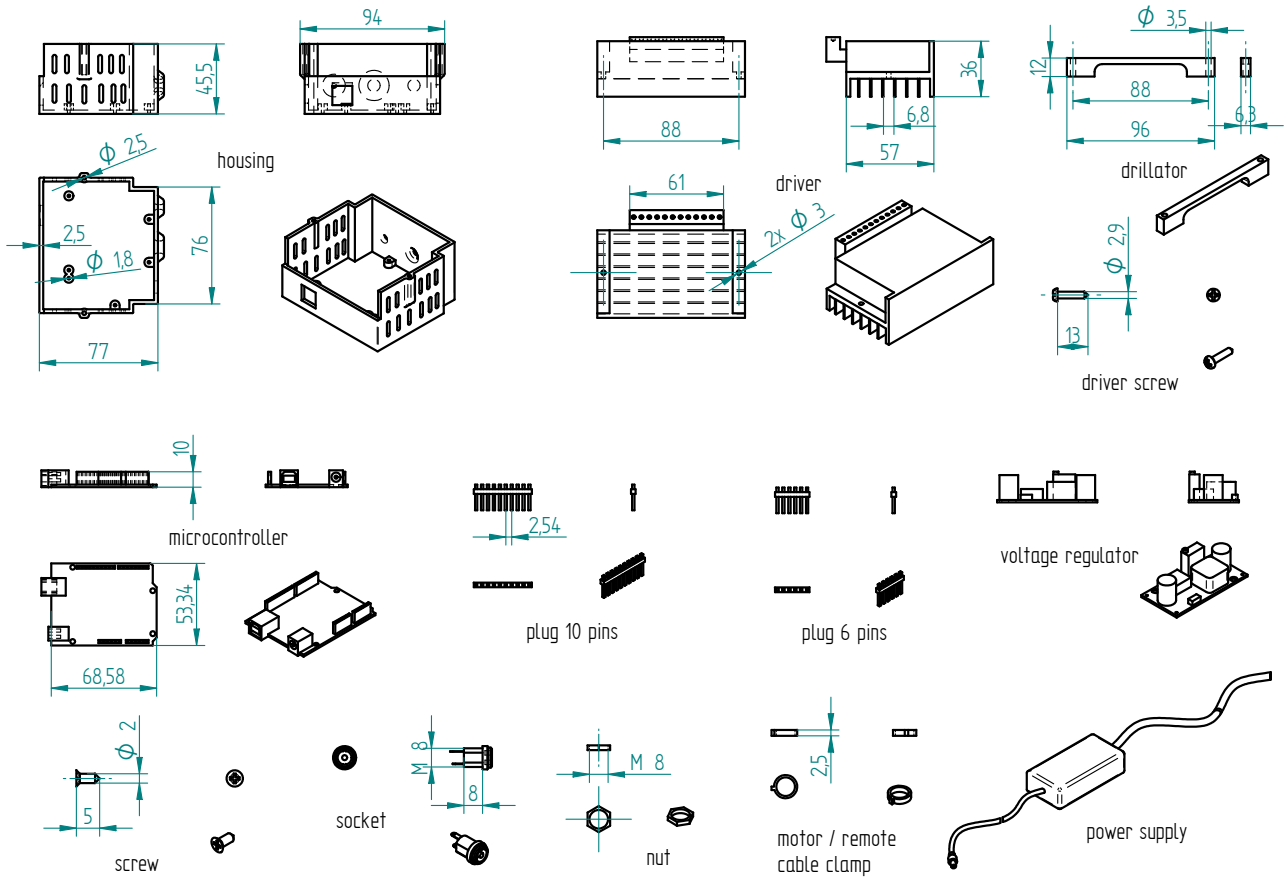


Figure 4.1: Drawing of the **power unit a** parts

4.3 Required Tools and Components

- 1x 3D printer ;
- 1x PLA ;
- 1x STL file **housing** ;
- 1x STL file **drillator** ;
- 1x file ;
- 1x 3.5 mm drill bit ;
- 1x chamfer mill ;
- 1x screw driver ;
- 1x drill press ;
- 1x driller ;
- 1x clamp.

4.4 Manufacturing Instructions

1. 3D print the **housing**.
2. 3D print the **drillator**.
3. Clamp the **drillator** on the **driver** (see section Drawing).
4. On a drill press, drill a 3.5 mm hole.
5. File or chamfer the hole.
6. Wire all connection (see section **wiring**).
7. Tighten the **motor cable clamp** and the **remote cable clamp**.
8. Assemble the **voltage regulator**, the **microcontroller**, the **socket** and close the **housing** with the **driver**.

4.5 Wiring

4.5.1 Wiring diagram

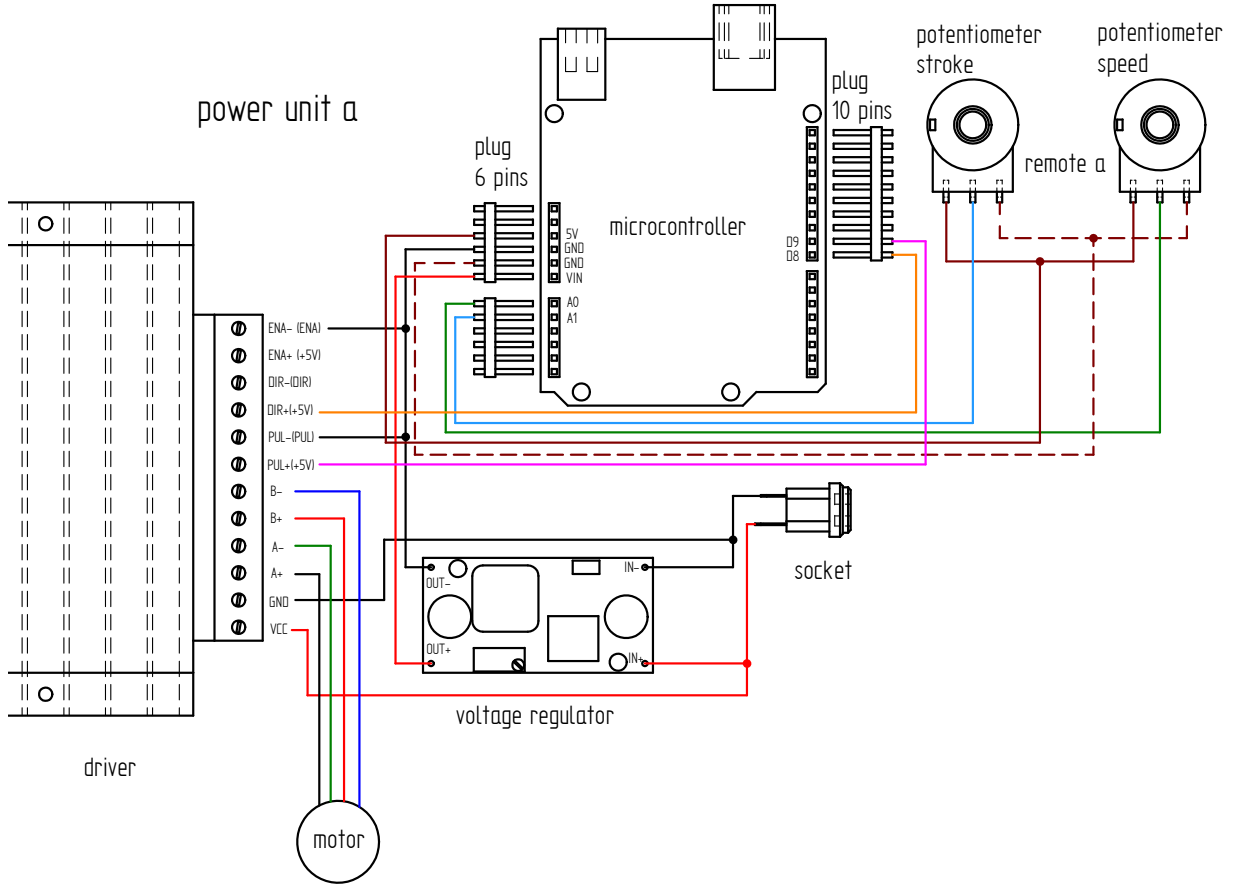


Figure 4.2: Wiring diagram

4.5.2 Parts list

Table 4.2: Parts list for wiring **power unit a**

Qty	Part	Description	Material
1	**power supply cable**	plug depends on country 110 V or 220 V	-
1	**motor cable**	4 poles 0.5mm2 length : 1 m[1]	
1	**wire**	0.5mm2 length : 1 m	cooper
1	**wire**	0.75mm2 length : 0.50 m	cooper
1	**RJ-45 cable**	8 cores length : 2.5 m	3 mm diameter

[1]If the motor is not supplied with its own cable, refer to Appendix C, page 177, for instructions on how to attach it.

4.5.3 Required Tools and Components

- 1x wire cutter ;
- 1x wire stripper ;
- 1x terminal crimping tool ;
- 1x multimeter (voltmeter) ;
- 1x soldering iron ;
- 1x solder ;
- 1x gauge ;
- 1x screwdriver 0 ;
- 1x water pump pliers ;
- 1x electrical tape.

4.5.4 Wiring Instructions

The lengths and cross-sectional areas of the wires are listed in table 4.3, page 133.

Remark : Wire the components before installing them into the **housing**.

1. Adjust the DIP switches on the driver to set the desired micro-step resolution and output current, referring to the driver's tables for the correct settings:
   - Micro-step resolution: 1600 → S1 = OFF, S2 = ON, S3 = OFF
   - Current: 3.5A (peak 4A) → S4 = OFF, S5 = OFF, S6 = OFF
2. Solder four wires to the **socket** (see Terminals Connection and Wire Details in Table 4.3, page 133, and Wiring Diagram4.2, page131).
3. Secure the **socket** to the **housing**.
4. Connect the **socket** to the **voltage regulator** (IN- and IN+).
5. Use a multimeter to adjust the output of the **voltage regulator** to 5V.
6. Solder the four wires to the corresponding pins on the **voltage regulator** :
   - Connect a wire from the **socket** to IN+ (input positive).
   - Connect a wire from the **socket** to IN- (input negative).
   - Connect a wire to OUT+ (output positive).
   - Connect a wire to OUT- (output negative).

7. If the motor does not already have a cable installed, solder four wires to the motor. See **Appendix: Attach the motor cable** C, page 177, for instructions on how to attach it.[2]

8. Complete all wiring connections (see Terminals Connection and Wire Details in Table 4.3, page 133, and Wiring Diagram4.2, page131).

9. Wire the **remote-controller-a** (if not yet done).

10. Secure all components inside the **housing**.

11. Upload the firmware (see Section ...).

4.5.5 Terminals Connections and Wires details

Table 4.3: Connections and wire details

Connections	length [cm]	section [mm2]
+_socket - IN+_voltage regulator	...	0.25
+_socket - VCC_driver	...	0.75
-_socket - IN-_voltage regulator	...	0.25
-_socket - GND_driver	...	0.25
OUT+_voltage regulator - VIN_plug 6 pins	...	0.25
OUT-_voltage regulator - ENA-_driver	...	0.25
ENA-_driver - GND_plug 6 pins	...	0.25
ENA-_driver - PUL-_driver	...	0.25
PUL+_driver - D9_plug 10 pins	...	0.25
DIR+_driver - D8_plug 10 pins	...	0.25
A+_driver - black_motor	...	0.75
A-_driver - green_motor	...	0.75
B+_driver - red_motor	...	0.75
B-_driver - blue_motor	...	0.75
A0_plug 6 pins - middle-pin_remote speed	250	0.15
A1_plug 6 pins - middle-pin_remote stroke	250	0.15
GND_plug 6 pins - left-pin_remote stroke and speed	250	0.15
5V_plug 6 pins - right-pin_remote stroke and speed	250	0.15

4.6 Firmware

After all components have been installed and wired inside the **housing**, it is time to upload the firmware to the **microcontroller**.

[2]It is much easier if you can get a motor with the cable already wired.

4.6.1 m1

The firmware source code for the machine **m1** is located in the `firmware` directory. A portion of the firmware code is shown below.

To upload the firmware, please follow the steps described in Appendix B (page 175).

```
// Comme le fait de lire la vitesse du potentiom\'etre prend relativement beaucoup de temps,
// cela r\'eduit la vitesse de pulsation de la pin 9. Pour parer \'a ceci le programme a \'et\'e adapt\'e
// pour lire la vitesse tous les 300 it\'erations \'a basse vitesse.
// Lorsque la vitesse du potentiom\'etre d\'epasse v\_max\_inv qui est la vitesse maximale \'a laquelle
// le moteur ne d\'ecroche pas \'a l'inversion du sens de rotation, des boucles d'acc\'el\'erations et de
// d\'ec\'el\'eration sont requises pour ne pas faire d\'ecrocher le moteur lors des inversions de sens de
// rotations. (avec ceci, il est possible de diminuer le d\'elai entre pulse \'a haute vitesse ce
// qui augmente la vitesse) Comme la vitesse est rapide la vitesse est alors lue apr\'es un cycle
// complet de va-et-vient. Pour simplifier, la course n'est lue qu'apr\'es un cycle complet de va-et-vient.
// Un autre point important est de lire la vitesse souvent \'a basse vitesse :
// par exemple si la vitesse est au mini et la course est grande, alors cela prendra une \'eternit\'e
// pour que le va-et-vient se termine jusqu'\'a la prochaine lecture de vitesse.
// L'acc\'el\'eration et la d\'ec\'el\'eration est lin\'eaire (apr\'es un cycle de pulse, le d\'elai est soustrait pour
// l'acc\'el\'eration ou additionn\'e de 1 pour la d\'ecc\'el\'eration).



#define step_pin 9          // Pin 9 connected to Steps pin on ST-M5045 ou ... c'est la pin du pulse
                            // (un pulse c'est un pas en mode full
                            // ou en mode 1600pas/rev : 8 pulses pour un pas avec un motor de 1.8deg
                            // ou 200pas/rev)
#define dir_pin 8           // Pin 8 connected to Direction pin
#define home_switch 12      // Pin 12 connected to Home Switch (MicroSwitch)
#define ref 0               // c'est le 0 ici l'inversion est faite en mode basse vitesse
                            // (sans acc\'el\'eration ni d\'ec\'el\'eration)


```

```
28 //**********************PARAMETRES MODIFIABLES
      ***********************************************************
29
30 #define v_max 40              // C'est la vitesse maximale lue par le
      potentiom\'etre de vitesse (d\'elai en
31                               // microseconde entre deux pulses) 30 50
                                    45 55 65 70 65 Valeur original 50.
32 #define v_min 1200            // C'est la vitesse minimum lue par le
      potentiom\'etre de vitesse (d\'elai en
33                               // microseconde entre deux pulses)
34 #define v_max_inv 200         // C'est la vitesse maximale \'a laquelle
       le moteur ne d\'ecroche pas 200 280
35                               // Valeur pr\'ec\'edente=200 \'a l'
                                    inversion de sens de rotation (200
                                    pour Gecko
36                               // et 200 pour 1600pas/rev?). En dessous
                                    de cette vitesse, l'acc\'el\'eration
37                               // et la d\'ec\'el\'eration ne sont pas
                                    requises. C'est pourquoi la course
                                    peut \^etre
38                               // plus petite car il n'y a pas besoin de
                                     distance de freinage. \'A cette
                                    petite
39                               // course le va-et-vient est tellement
                                    rapide que \c ca vibre. On retrouve
                                    ici
40                               // le mode vibro.
41 #define course_max 2968       // C'est la course maximale lue par le
      potentiom\'etre de course 2150 2125
42                               // 2100 2080 origine 2320 2500 Cette
                                    valeur d\'epende de la longueur de la
43                               // machine.
44
45 #define marge 30              // C'est la marge ou d\'ecalage de la r\'
      ef\'erence par rapport \'a la position du
46                               // bras \'a la mise sous tension de la
                                    machine en principe en but\'ee du c\^
                                    ot\'e
47                               // vert ou c\^ot\'e rouge. Ceci assure
                                    que la partie mobile ne vienne cogn\'
                                    er
48                               // sur l'un des c\^ot\'es. Valeur
                                    originale = 50.
49 //
      ***********************************************************************
50
51
52 int course_min = 296;        // C'est la course minimum lue par le
      potentiom\'etre de course. Qui corresond
```

```
53                                  // \‘a la course minimum pour l’acc\’el\’
                                       eration et la d\’ec\’el\’eration \‘a
                                       haute vitesse.
54                                  // (vitesse \‘a laquelle la distance de
                                       freinage/acc\’el\’eration est requise)
                                       .
55                                  // Soit course_min > 2*(v_max_inv - v_max
                                       ) = distance max de freinage ou
56                                  // d’acc\’el\’eration.
```

Listing 4.1: Partial code: firmware.ino

4.6.2 m2

The firmware source code for the machine **m2** is located in the `firmware` directory. A portion of the firmware code is shown below.

To upload the firmware, please follow the steps described in Appendix B (page 175).

```
1  // Comme le fait de lire la vitesse du potentiom\‘etre prend
       relativement beaucoup de temps,
2  // cela r\’eduit la vitesse de pulsation de la pin 9. Pour parer \‘a
       ceci le programme a \’et\’e adapt\’e
3  // pour lire la vitesse tous les 300 it\’erations \‘a basse vitesse.
4  // Lorsque la vitesse du potentiom\‘etre d\’epasse v\_max\_inv qui
       est la vitesse maximale \‘a laquelle
5  // le moteur ne d\’ecroche pas \‘a l’inversion du sens de rotation,
       des boucles d’acc\’el\’erations et de
6  // d\’ec\’el\’eration sont requises pour ne pas faire d\’ecrocher le
       moteur lors des inversions de sens de
7  // rotations. (avec ceci, il est possible de diminuer le d\’elai
       entre pulse \‘a haute vitesse ce
8  // qui augmente la vitesse) Comme la vitesse est rapide la vitesse
       est alors lue apr\‘es un cycle
9  // complet de va-et-vient. Pour simplifier, la course n’est lue qu’
       apr\‘es un cycle complet de va-et-vient.
10 // Un autre point important est de lire la vitesse souvent \‘a basse
       vitesse :
11 // par exemple si la vitesse est au mini et la course est grande,
       alors cela prendra une \’eternit\’e
12 // pour que le va-et-vient se termine jusqu’\‘a la prochaine lecture
       de vitesse.
13 // L’acc\’el\’eration et la d\’ec\’el\’eration est lin\’eaire (apr\‘
       es un cycle de pulse, le d\’elai est soustrait pour
14 // l’acc\’el\’eration ou additionn\’e de 1 pour la d\’ecc\’el\’
       eration).
15
16
17
18 #define step_pin 9          // Pin 9 connected to Steps pin on ST-
       M5045 ou ... c’est la pin du pulse
```

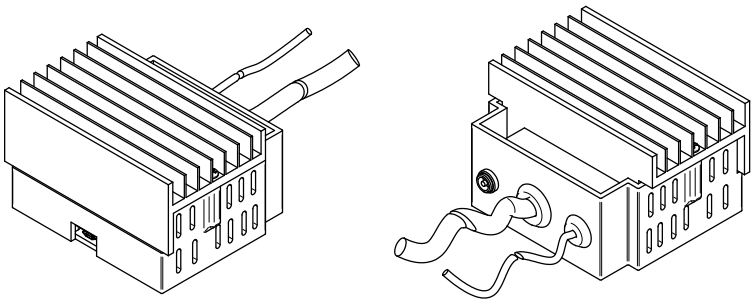
```
19                              // (un pulse c'est un pas en mode full
20                              // ou en mode 1600pas/rev : 8 pulses pour
                                    un pas avec un motor de 1.8deg
21                              // ou 200pas/rev)
22 #define dir_pin 8            // Pin 8 connected to Direction pin
23 #define home_switch 12       // Pin 12 connected to Home Switch (
   MicroSwitch)
24 #define ref 0                // c'est le 0 ici l'inversion est faite
   en mode basse vitesse
25                              // (sans acc\'el\'eration ni d\'ec\'el\'
                                   eration)
26
27
28 //**********************PARAMETRES MODIFIABLES
   ***********************************************************
29
30 #define v_max 40             // C'est la vitesse maximale lue par le
   potentiom\'etre de vitesse (d\'elai en
31                              // microseconde entre deux pulses) 30 50
                                   45 55 65 70 65 Valeur original 50.
32 #define v_min 1200           // C'est la vitesse minimum lue par le
   potentiom\'etre de vitesse (d\'elai en
33                              // microseconde entre deux pulses)
34 #define v_max_inv 200        // C'est la vitesse maximale \'a laquelle
    le moteur ne d\'ecroche pas 200 280
35                              // Valeur pr\'ec\'edente=200 \'a l'
                                   inversion de sens de rotation (200
                                   pour Gecko
36                              // et 200 pour 1600pas/rev?). En dessous
                                   de cette vitesse, l'acc\'el\'eration
37                              // et la d\'ec\'el\'eration ne sont pas
                                   requises. C'est pourquoi la course
                                   peut \^etre
38                              // plus petite car il n'y a pas besoin de
                                    distance de freinage. \'A cette
                                   petite
39                              // course le va-et-vient est tellement
                                   rapide que \c ca vibre. On retrouve
                                   ici
40                              // le mode vibro.
41 #define course_max 2968      // C'est la course maximale lue par le
   potentiom\'etre de course 2150 2125
42                              // 2100 2080 origine 2320 2500 Cette
                                   valeur d\'epende de la longueur de la
43                              // machine.
44
45 #define marge 30             // C'est la marge ou d\'ecalage de la r\'
   ef\'erence par rapport \'a la position du
46                              // bras \'a la mise sous tension de la
                                   machine en principe en but\'ee du c\^
```

```
                                ot\'e
47                              // vert ou c\^ot\'e rouge. Ceci assure
                                   que la partie mobile ne vienne cogn\'
                                   er
48                              // sur l'un des c\^ot\'es. Valeur
                                   originale = 50.
49 //
   **********************************************************************
50
51
52 int course_min = 296;        // C'est la course minimum lue par le
   potentiom\'etre de course. Qui corresond
53                              // \'a la course minimum pour l'acc\'el\'
                                   eration et la d\'ec\'el\'eration \'a
                                   haute vitesse.
54                              // (vitesse \'a laquelle la distance de
                                   freinage/acc\'el\'eration est requise)
                                   .
55                              // Soit course_min > 2*(v_max_inv - v_max
                                   ) = distance max de freinage ou
56                              // d'acc\'el\'eration.
```

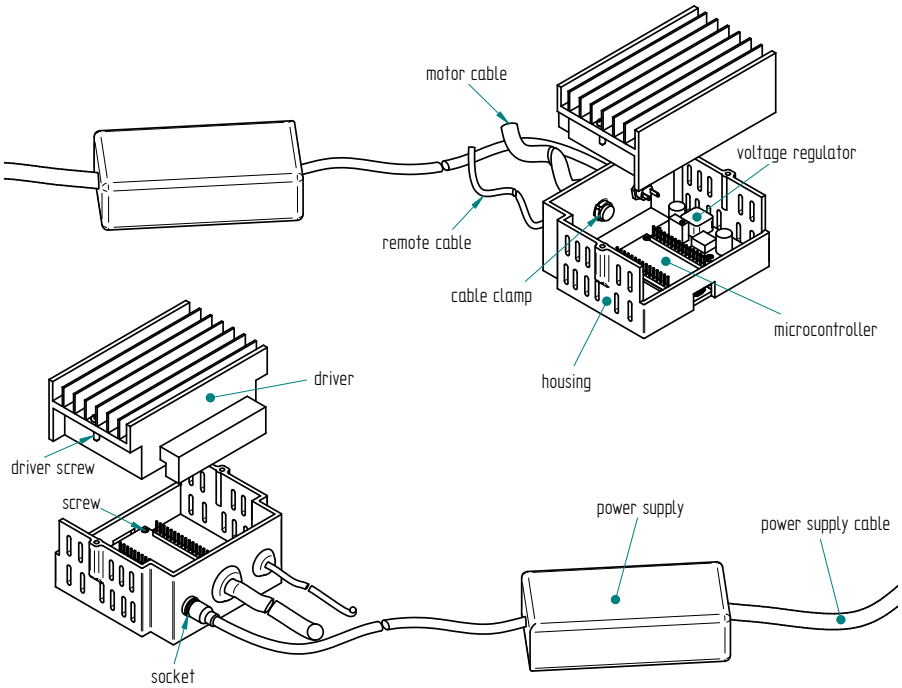
Listing 4.2: Partial code: firmware.ino

Chapter 5

power unit e



This chapter explains how to build the **power unit e**.



5.1 Parts list

Table 5.1: Parts list of **power unit e**

Qty	Part	Description	Material
1	**housing**	3D printed	PLA
1	**driver**	TB6600	-
1	**microcontroller**	ESP32 30 pins	-
1	**voltage regulator**	LM2596	-
1	**socket**	2.1/5.5	-
1	**nut**	M8	-
6	**screw**	M2 x 5	brass
2	**driver screw**	2.9 x 13	stainless steel
1	**motor cable clamp**	2.5	nylon (cable tie)
1	**remote cable clamp**	2.5	nylon (cable tie)
1	**power supply**	110-220V/24V 6A	-
1	**power supply cable**	plug depends on country 110 V or 220 V	-

5.2 Drawing

See Figure 5.1, page 141.

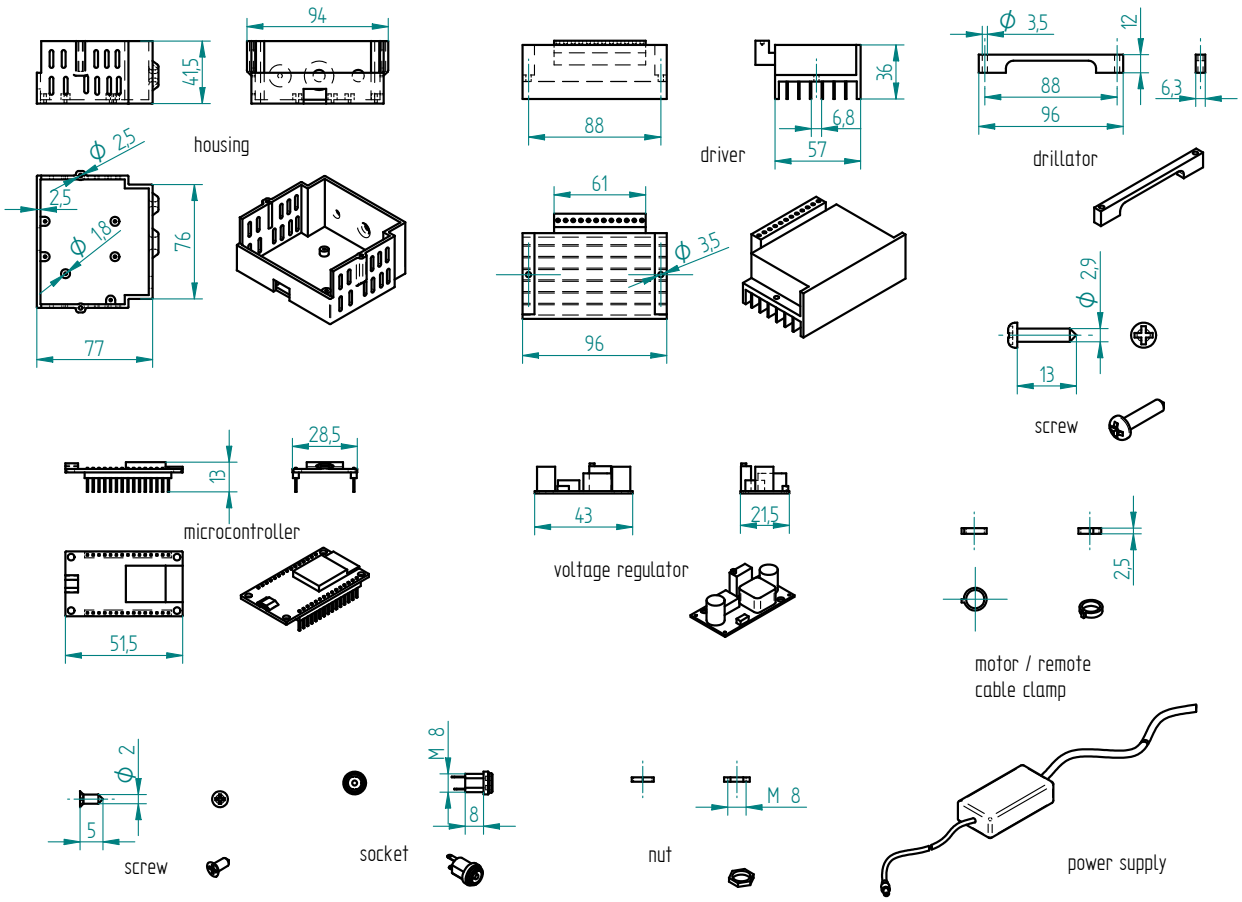


Figure 5.1: Drawing of the **power unit e** parts

5.3 Required Tools and Components

- 1x 3D printer ;
- 1x PLA ;
- 1x STL file **housing** ;
- 1x STL file **drillator** ;
- 1x file ;
- 1x 3.5 mm drill bit ;
- 1x chamfer mill ;
- 1x screw driver ;
- 1x drill press ;
- 1x driller ;
- 1x clamp.

5.4 Manufacturing Instructions

1. 3D print the **housing**.
2. 3D print the **drillator**.
3. Clamp the **drillator** on the **driver** (see section drawing).
4. On a drill press, drill a 3.5 mm hole.
5. File or chamfer the hole.
6. Wire all connection (see section **Wiring**).
7. Tighten the **motor cable clamp** and the **remote cable clamp**.
8. Assemble the **voltage regulator**, the **microcontroller**, the **socket** and close the **housing** with the **driver**.

5.5 Wiring

5.5.1 Wiring diagram

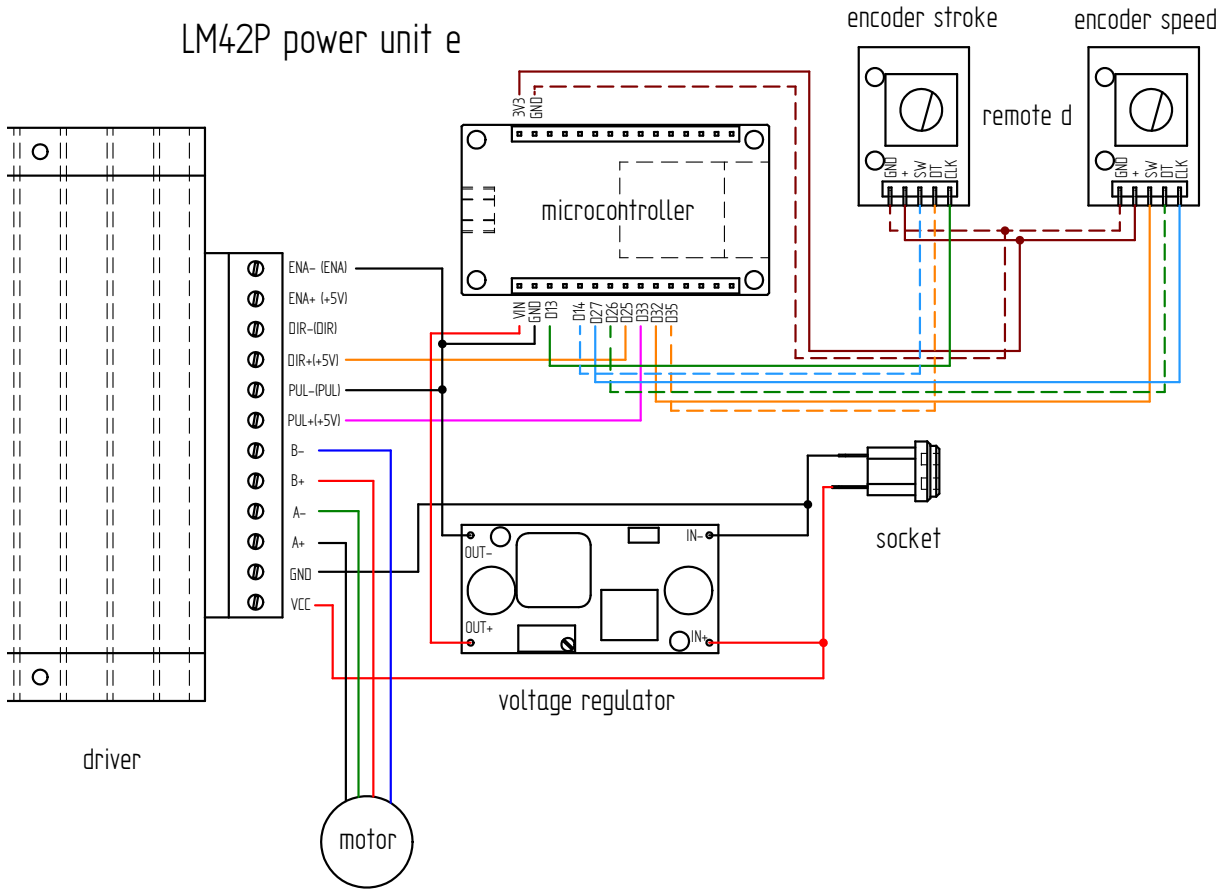


Figure 5.2: Wiring diagram

5.5.2 Parts list

Table 5.2: Parts list for wiring **power unit e**

Qty	Part	Description	Material
1	**motor cable**	4 poles 0.5mm2 length : 1 m[1]	
1	**wire**	0.5mm2 length : 1 m	cooper
1	**wire**	0.75mm2 length : 0.50 m	cooper
1	**RJ-45 cable**	8 cores length : 2.5 m	3 mm diameter

[1]If the motor is not supplied with its own cable, refer to Appendix C, page 177, for instructions on how to attach it.

5.5.3 Required Tools and Components

- 1x wire cutter ;
- 1x wire stripper ;
- 1x terminal crimping tool ;
- 1x multimeter (voltmeter) ;
- 1x soldering iron ;
- 1x solder ;
- 1x gauge ;
- 1x screwdriver 0 ;
- 1x water pump pliers ;
- 1x electrical tape.

5.5.4 Wiring Instructions

The lengths and cross-sectional areas of the wires are listed in table 5.3, page 145.

Remark : Wire the components before installing them into the **housing**.

1. Adjust the DIP switches on the driver to set the desired micro-step resolution and output current, referring to the driver's tables for the correct settings:
   - Micro-step resolution: 1600 → S1 = OFF, S2 = ON, S3 = OFF
   - Current: 3.5A (peak 4A) → S4 = OFF, S5 = OFF, S6 = OFF
2. Solder four wires to the **socket** (see Terminals Connection and Wire Details in Table 5.3, page 145, and Wiring Diagram5.2, page143).
3. Secure the **socket** to the **housing**.
4. Connect the **socket** to the **voltage regulator** (IN- and IN+).
5. Use a multimeter to adjust the output of the **voltage regulator** to 5V.
6. Solder the four wires to the corresponding pins on the **voltage regulator** :
   - Connect a wire from the **socket** to IN+ (input positive).
   - Connect a wire from the **socket** to IN- (input negative).
   - Connect a wire to OUT+ (output positive).
   - Connect a wire to OUT- (output negative).

7. If the motor does not already have a cable installed, solder four wires to the motor. See **Appendix: Attach the motor cable** C, page 177, for instructions on how to attach it.[2]

8. Complete all wiring connections (see Terminals Connection and Wire Details in Table 5.3, page 145, and Wiring Diagram5.2, page143).

9. Wire the **remote-controller-d**[3] (if not yet done).

10. Secure all components inside the **housing**.

11. Upload the firmware (see Section Firmware).

5.5.5 Terminals Connections and Wires details

Table 5.3: Connections and wire details

Connections	length [cm]	section [mm2]
+_socket - IN+_voltage regulator	...	0.25
+_socket - VCC_driver	...	0.75
-_socket - IN-_voltage regulator	...	0.25
-_socket - GND_driver	...	0.25
OUT+_voltage regulator - VIN_microcontroller	...	0.25
OUT-_voltage regulator - ENA-_driver	...	0.25
ENA-_driver - GND_microcontroller	...	0.25
ENA-_driver - PUL-_driver	...	0.25
PUL+_driver - D33_microcontroller	...	0.25
DIR+_driver - D25_microcontroller	...	0.25
A+_driver - black_motor	...	0.75
A-_driver - green_motor	...	0.75
B+_driver - red_motor	...	0.75
B-_driver - blue_motor	...	0.75
D13_microcontroller - CLK_encoder stroke	250	0.15
D14_microcontroller - SW_encoder stroke	250	0.15
D27_microcontroller - CLK_encoder speed	250	0.15
D26_microcontroller - DT_encoder speed	250	0.15
D32_microcontroller - SW_encoder speed	250	0.15
D35_microcontroller - DT_encoder stroke	250	0.15
3V3_microcontroller - +_encoder stroke and speed	250	0.15
GND_microcontroller - GND_encoder stroke and speed	250	0.15

5.6 Firmware

After all components have been installed and wired inside the **housing**, it is time to upload the firmware to the **microcontroller**.

[2]It is much easier if you can get a motor with the cable already wired.
[3]cut the RJ-45 plug and use only the cable

5.6.1 m1

The firmware source for the machine **m1** code is located in the `firmware` directory. A portion of the firmware code is shown below.

To upload the firmware, please follow the steps described in Appendix B (page 175).

```
//speed rotary encoder
#define ROTARY_ENCODER_A_PIN 27 //CLK
#define ROTARY_ENCODER_B_PIN 26 //DT
#define ROTARY_ENCODER_BUTTON_PIN 32 //SW
#define ROTARY_ENCODER_STEPS 4
#define ROTARY_ENCODER_ACCELERATION 2000 //30000 3000
AiEsp32RotaryEncoder rotaryEncoder = AiEsp32RotaryEncoder(
   ROTARY_ENCODER_A_PIN, ROTARY_ENCODER_B_PIN,
   ROTARY_ENCODER_BUTTON_PIN, -1, ROTARY_ENCODER_STEPS);

// stroke rotary encoder
#define ROTARY_ENCODER2_A_PIN 13 //CLK
#define ROTARY_ENCODER2_B_PIN 35 //DT
#define ROTARY_ENCODER2_BUTTON_PIN 14 //SW
#define ROTARY_ENCODER2_STEPS 4
#define ROTARY_ENCODER2_ACCELERATION 7000
AiEsp32RotaryEncoder rotaryEncoder2 = AiEsp32RotaryEncoder(
   ROTARY_ENCODER2_A_PIN, ROTARY_ENCODER2_B_PIN,
   ROTARY_ENCODER2_BUTTON_PIN, -1, ROTARY_ENCODER2_STEPS);

void IRAM_ATTR readEncoderISR()
{
  rotaryEncoder.readEncoder_ISR();
  rotaryEncoder2.readEncoder_ISR();
}

// IO pin assignments
const int MOTOR_STEP_PIN = 33;
const int MOTOR_DIRECTION_PIN = 25;
```

Listing 5.1: Partial code: firmware.ino

5.6.2 m2

The firmware source code for the machine **m2** is located in the `firmware` directory. A portion of the firmware code is shown below.

To upload the firmware, please follow the steps described in Appendix B (page 175).

```
//speed rotary encoder
#define ROTARY_ENCODER_A_PIN 27 //CLK
#define ROTARY_ENCODER_B_PIN 26 //DT
#define ROTARY_ENCODER_BUTTON_PIN 32 //SW
#define ROTARY_ENCODER_STEPS 4
#define ROTARY_ENCODER_ACCELERATION 2000 //30000 3000
```

```
7  AiEsp32RotaryEncoder rotaryEncoder = AiEsp32RotaryEncoder(
       ROTARY_ENCODER_A_PIN, ROTARY_ENCODER_B_PIN,
       ROTARY_ENCODER_BUTTON_PIN, -1, ROTARY_ENCODER_STEPS);
8
9  // stroke rotary encoder
10 #define ROTARY_ENCODER2_A_PIN 13 //CLK
11 #define ROTARY_ENCODER2_B_PIN 35 //DT
12 #define ROTARY_ENCODER2_BUTTON_PIN 14 //SW
13 #define ROTARY_ENCODER2_STEPS 4
14 #define ROTARY_ENCODER2_ACCELERATION 7000
15 AiEsp32RotaryEncoder rotaryEncoder2 = AiEsp32RotaryEncoder(
       ROTARY_ENCODER2_A_PIN, ROTARY_ENCODER2_B_PIN,
       ROTARY_ENCODER2_BUTTON_PIN, -1, ROTARY_ENCODER2_STEPS);
16
17 void IRAM_ATTR readEncoderISR()
18 {
19   rotaryEncoder.readEncoder_ISR();
20   rotaryEncoder2.readEncoder_ISR();
21 }
22
23 // IO pin assignments
24 const int MOTOR_STEP_PIN = 33;
25 const int MOTOR_DIRECTION_PIN = 25;
```

Listing 5.2: Partial code: firmware.ino

Chapter 6

remote control d

This is the digital remote control named **remote control d** (the letter d stands for digital). It can be used either with the **power unit p** or the **power unit e**.

Note that the **power unit p** uses a cable with an RJ-45 plug, while the **power unit e** does not, as its plug has been removed (cut off).

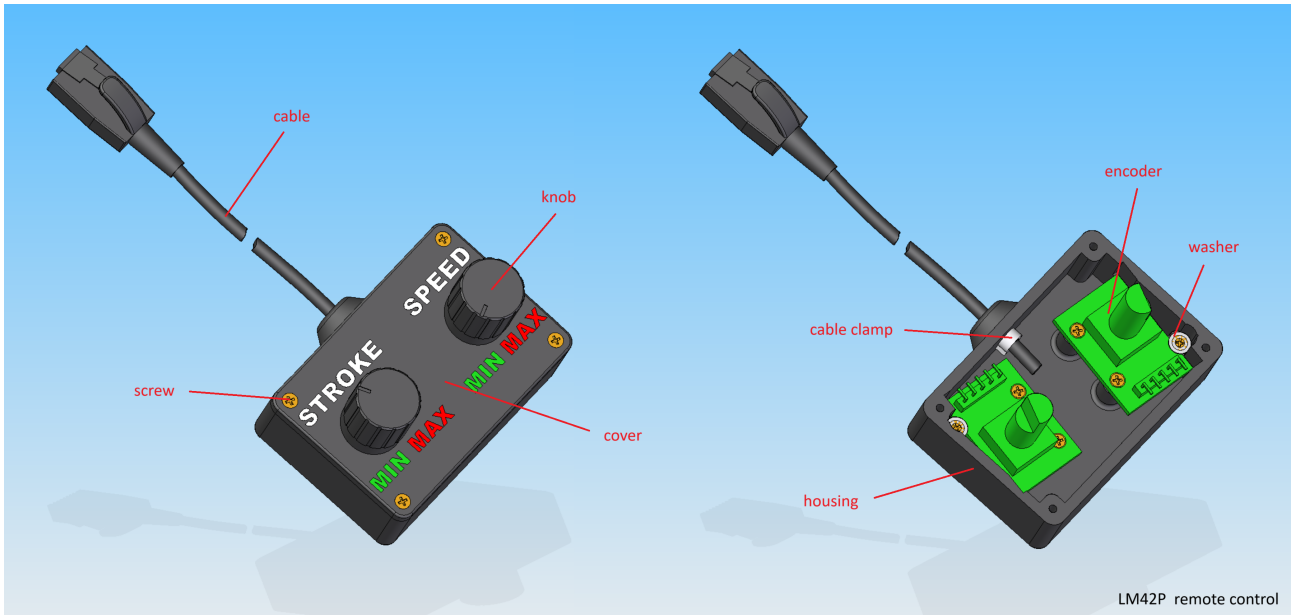


Figure 6.1: remote control d parts

6.1 Parts list

Table 6.1: Parts list of **remote control d**

Qty	Part	Description	Material
1	**housing**	3D printed	PLA
1	**cover**	3D printed	PLA
2	**encoder**	with switch	

continued on next page ...

... continued

Qty	Part	Description	Material
2	**knob**	14 x 16.5 mm	aluminium
1	**cable**	3 x 2500 mm LAN RJ45	-
1	**cable clamp**	2.5 mm	nylon
10	**screw**	2 x 10 mm	brass
1	**stroke inscription**	molded into cavity	pigmented white epoxy
1	**speed inscription**	molded into cavity	pigmented white epoxy
1	**min inscription**	molded into cavity	pigmented green epoxy
1	**max inscription**	molded into cavity	pigmented red epoxy

6.2 Drawing

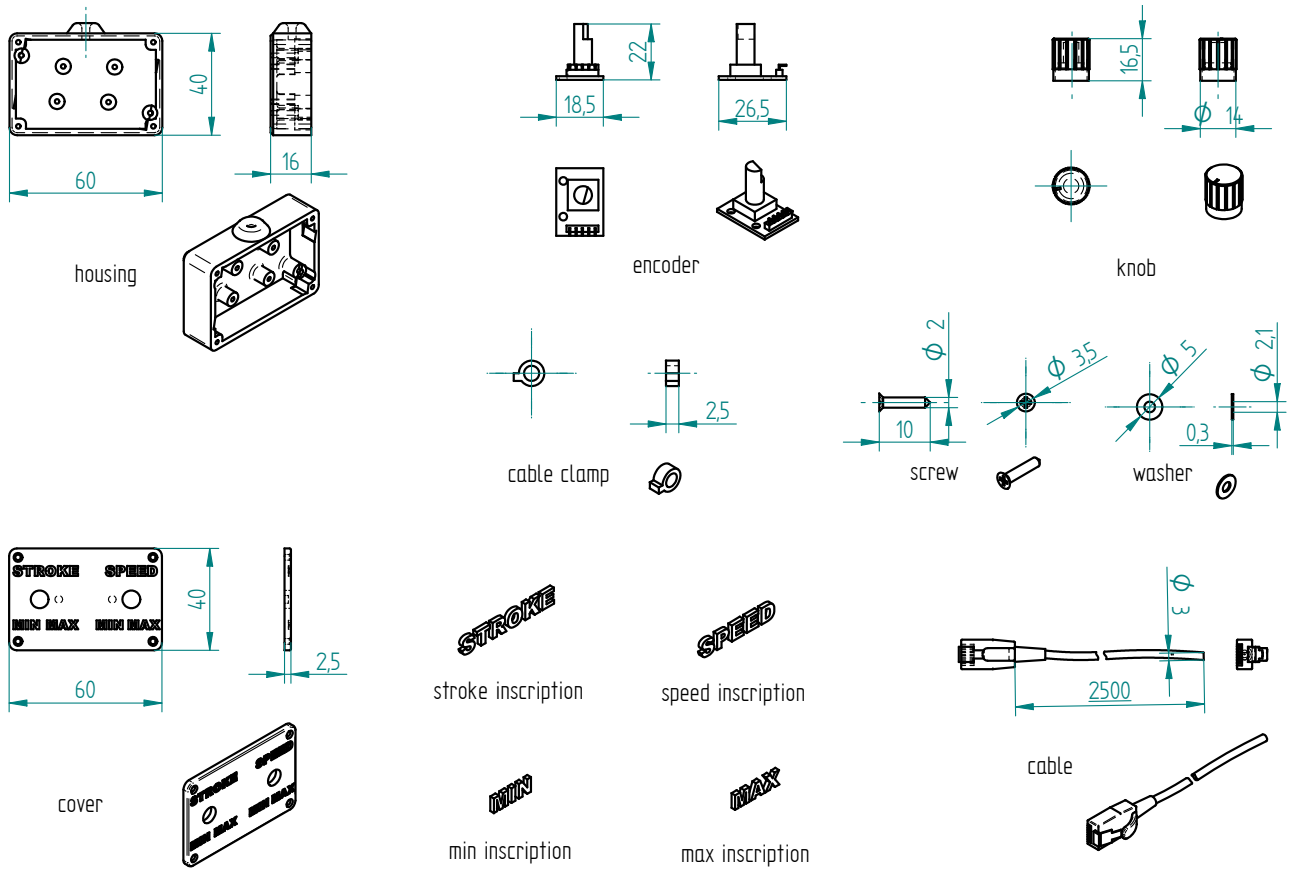


Figure 6.2: **remote control-d** parts drawing

6.3 Required Tools and Components

- 1x 3D printer ;
- 1x PLA ;
- 1x STL file **housing** ;
- 1x file ;
- 1x chamfer mill ;
- 1x screw driver ;
- ..g resine ;
- ..g hardener ;
- ..g pigmented white epoxy ;

- ..g pigmented green epoxy ;
- ..g pigmented red epoxy ;
- water sandpaper 80 ;
- water sandpaper 150 ;
- water sandpaper 220 ;
- water sandpaper 400.

6.4 Manufacturing Instructions

1. 3D print the **housing**.
2. 3D print the **cover**.
3. Prepare :
    - pigmented white epoxy
    - pigmented green epoxy
    - pigmented red epoxy.
4. Fill the cavities with the corresponding epoxy colors for the inscriptions.
5. Allow to cure for 24 hours.
6. Wet-sand the top of the **cover** up to 400-grit sandpaper.
7. Install both **potentiometers**.
8. Wire all connections (see Section 3.11, page 118).
9. Tighten the **remote cable clamp**.
10. Close the **housing** using the **cover**.

Chapter 7

remote control a

This is the digital remote control (the letter a stands for analogic). It is used with the **power unit a**[1].

Note that the **power unit a** uses a **remote cable** without an RJ-45 plug, so just cut it off.

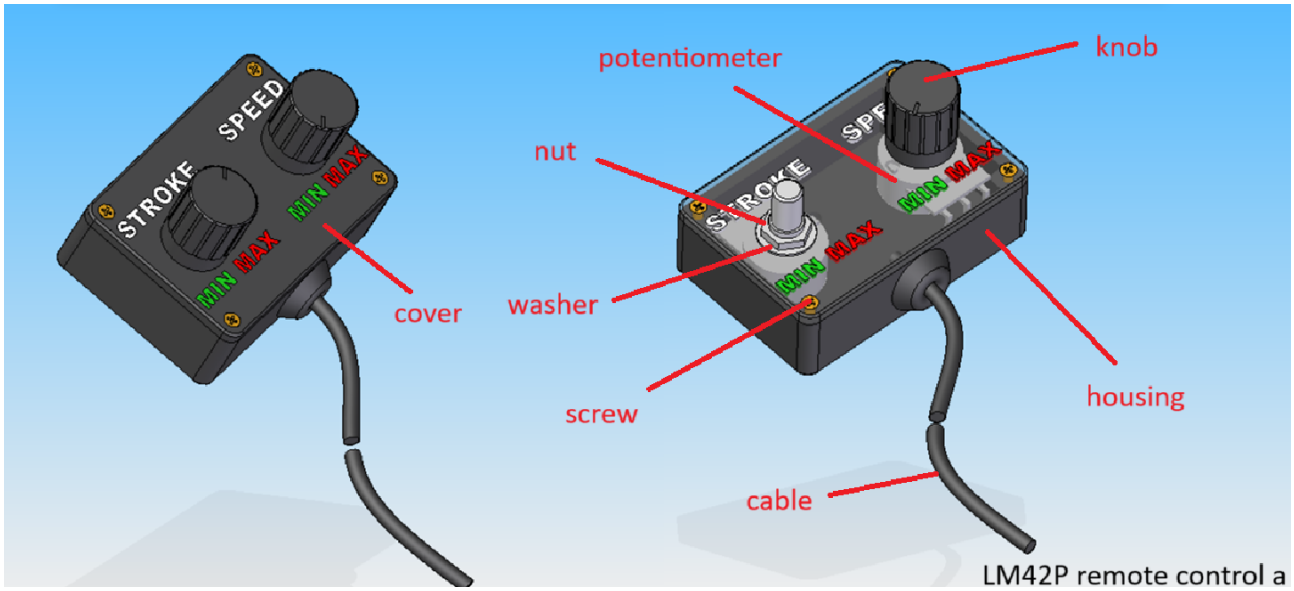


Figure 7.1: **remote control a** parts

7.1 Parts list

Table 7.1: Parts list of **remote control a**

Qty	Part	Description	Material
1	**housing**	3D printed	PLA
1	**cover**	3D printed	PLA

continued on next page ...

[1]It can be use also with **power unit e or p** but not showed in this documentation

... continued

Qty	Part	Description	Material
2	**encoder**	with switch	
2	**knob**	14 x 16.5 mm	aluminium
1	**cable**	3 x 2500 mm LAN RJ45 (without plug)	-
1	**cable clamp**	2.5 mm	nylon
4	**screw**	2 x 10 mm	brass
1	**stroke inscription**	molded into cavity	pigmented white epoxy
1	**speed inscription**	molded into cavity	pigmented white epoxy
1	**min inscription**	molded into cavity	pigmented green epoxy
1	**max inscription**	molded into cavity	pigmented red epoxy

7.2 Drawing

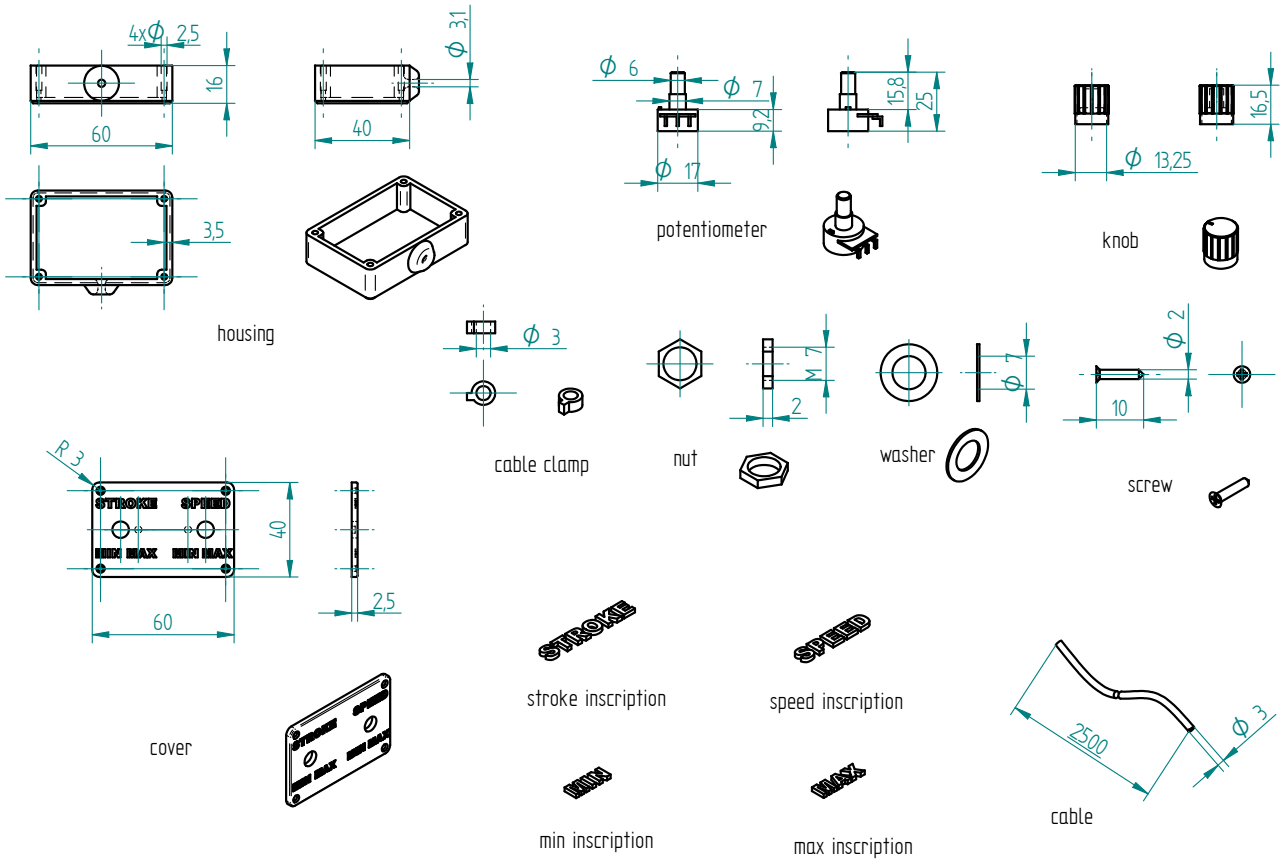


Figure 7.2: **remote control a** parts drawing

7.3 Required Tools and Components

- 1x 3D printer ;
- 1x PLA ;
- 1x STL file **housing** ;
- 1x file ;
- 1x chamfer mill ;
- 1x screw driver ;
- ..g resine ;
- ..g hardener ;
- ..g pigmented white epoxy ;

- ..g pigmented green epoxy ;
- ..g pigmented red epoxy ;
- Wet sandpaper, grit 80
- Wet sandpaper, grit 150
- Wet sandpaper, grit 220
- Wet sandpaper, grit 400.

7.4 Manufacturing Instructions

1. 3D print the **housing**.
2. 3D print the **cover**.
3. Prepare :
    - pigmented white epoxy
    - pigmented green epoxy
    - pigmented red epoxy.
4. Fill the cavities with the corresponding epoxy colors for the inscriptions.
5. Allow to cure for 24 hours.
6. Wet-sand the top of the **cover** up to 400-grit sandpaper.
7. Install both **potentiometers**.
8. Wire all connections (see Section 4.5, page 131).
9. Tighten the **remote cable clamp**.
10. Close the **housing** using the **cover**.

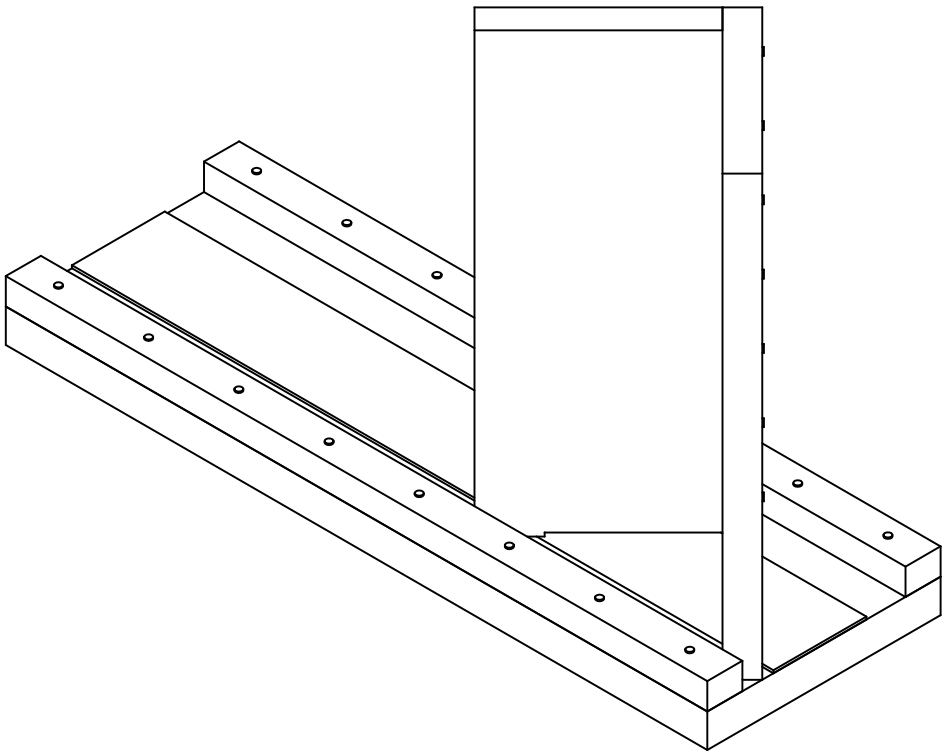
Appendix A

Shaped Tools

Contents

In this chapter, I introduce the tools required to build all the machines described in this building plan. I present the **perpendiculator**—a tool used to make the ends or faces of a tube, or any part, perfectly perpendicular.

A.1 perpendiculator



Contents

In this section I introduce how to build the **perpendiculator**. This tool has two assemblies the **plane** and the **slider**. They have both a paragraph in which all details are explained. In the paragraph **Assemblies** the whole tool are assembled with the sub-assemblies **plane** and **slider**. And in the paragraph **Normalized parts** are showed all the normalized parts which are used for the **plane** and the **slider** (for example **wooden glue**, **nails**).

A.1.1 Roadmap

In this section we can find the roadmap to build the **perpendiculator**. It's not necessary to follow straight all these points after another, but I think it's the most logical to do it like this :

1. prepare all stuff in the **Parts-list** with the tools showed in the **Tools-list** ;
2. assemble the **slider** ;
3. assemble the **base**.

A.1.2 Parts list

In this section we can find the whole list of parts that the **perpendiculator** needs, like :

- 1x **base** size 133x400x19 in MDF ;
- 1x **rectangular-wooden-list** size 15x20x1000 in beech for :
  - 2x **guide**.
- 1x **sandpaper** ;
- 1x **face-1** size 100x250x16 in MDF ;
- 1x **face-2** size 116x250x16 in MDF ;
- 1x **nails** (box) size 1.4x30 ;
- 1x **wooden glue** ;
- 1x **amidon glue**.

A.1.3 Tools list

In this section we can find the list of tools that we need to build the **perpendiculator**, like :

- 1x hammer ;
- 1x drill press ;
- 1x 1.4mm diameter drill ;
- 2x clamps ;
- 1x ruler ;
- sandpager.

A.1.4 Shaped parts

In this paragraph we can find all the shaped parts of the **perpendiculator**, like :

- **base** ;
- **guide** ;
- **sandpaper** ;
- **face-1** ;
- **face-2**.

base

Here is shown the information for the shaped part **base**.

Roadmap

1. order in a carpentry.

That's all for this part.

Drawing See figure A.1, page 161

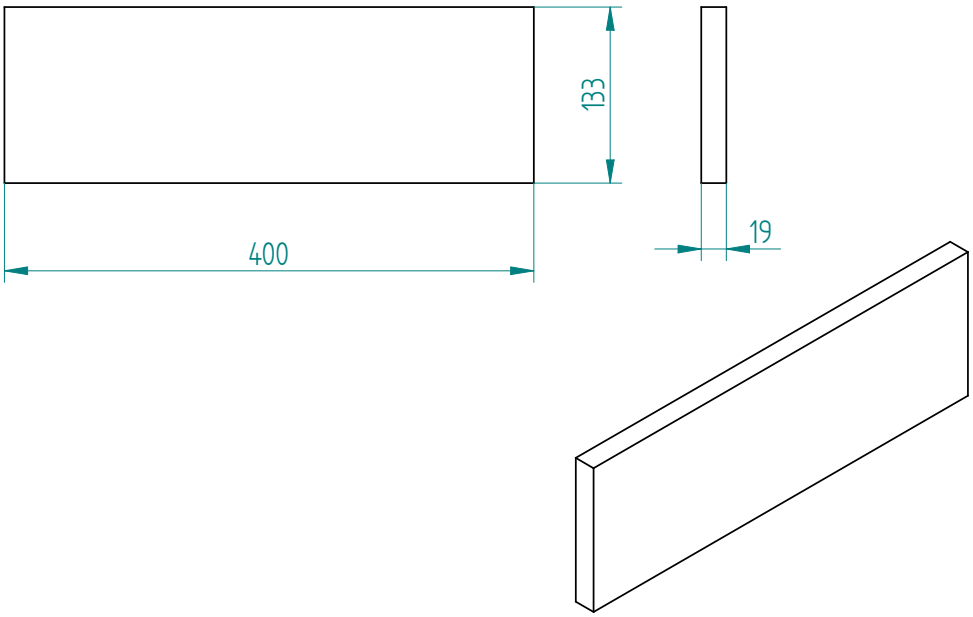


Figure A.1: Shaped part : **base** for **perpendiculator** tool

quantity 1 ;

material MDF ;

provider carpentry ;

price ?.

guide

This section shows how to build the **guide** of the **perpendiculator** tool.

Roadmap

1. order the **rectangular-wooden-list** see section A.1.5, 167 ;
2. ask at the carpentry to cut it at the good length (see the length on the figure A.2, page 162) ;
3. drill the holes with diameter 1.4mm (see figure A.2, page 162 for the positions).

Drawing See figure A.2, page 162

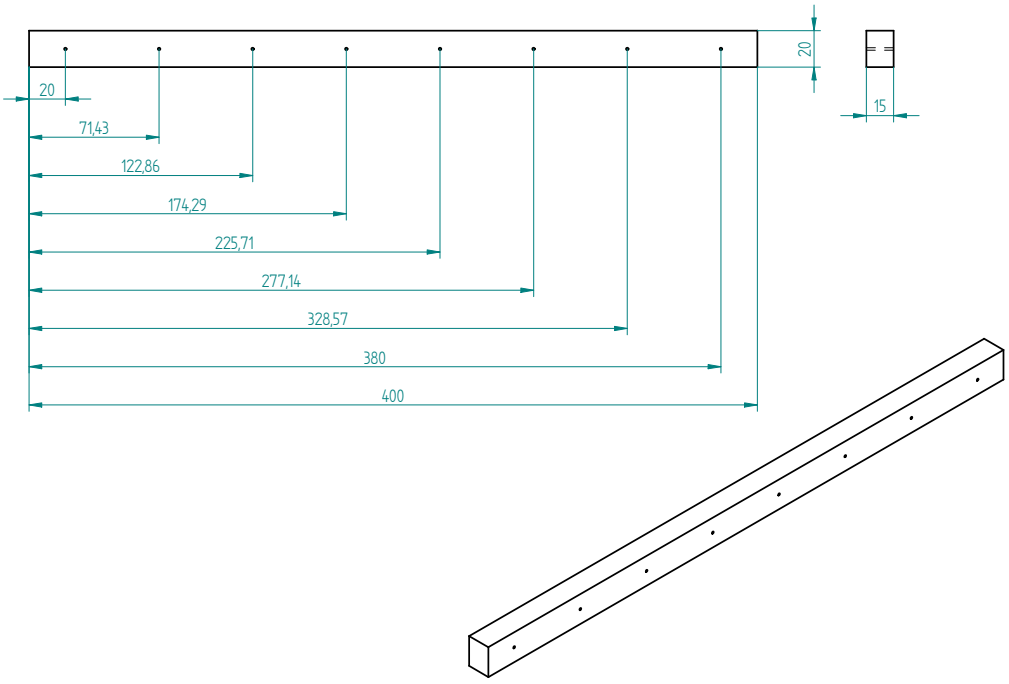


Figure A.2: Shaped part : **guide** for **perpendiculator** tool

quantity 2 ;

material beech ;

provider ironmongery ;

price ? .

sandpaper

Drawing See figure A.3, page 163

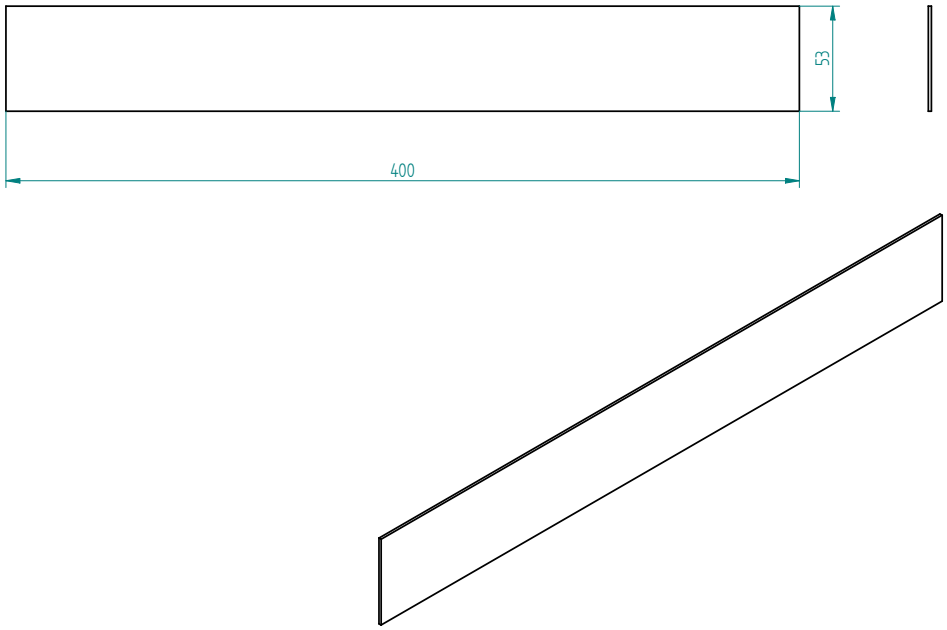


Figure A.3: Shaped part : **sandpaper** for **perpendiculator** tool

quantity 1 ;

material emery granularity : 80 ;

provider ironmongery ;

price ?.

face-1

Roadmap

1. order the part in a joinery see figure A.4, page 164 for dimensions.

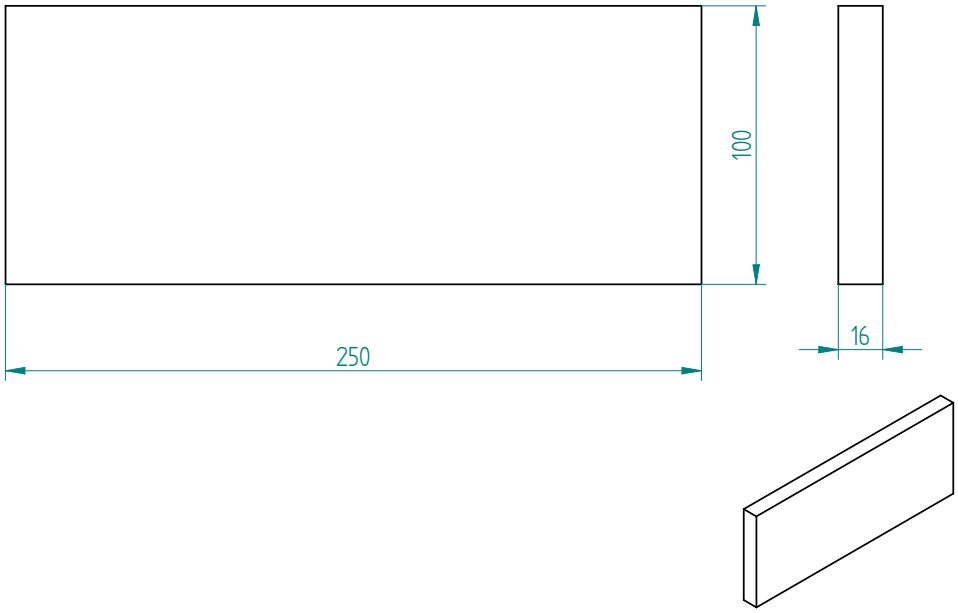


Figure A.4: Shaped part : **face-1-outsourcing** for **perpendiculator** tool

Drawing This is how the **face-1** looks at the end. See figure A.5, page 165

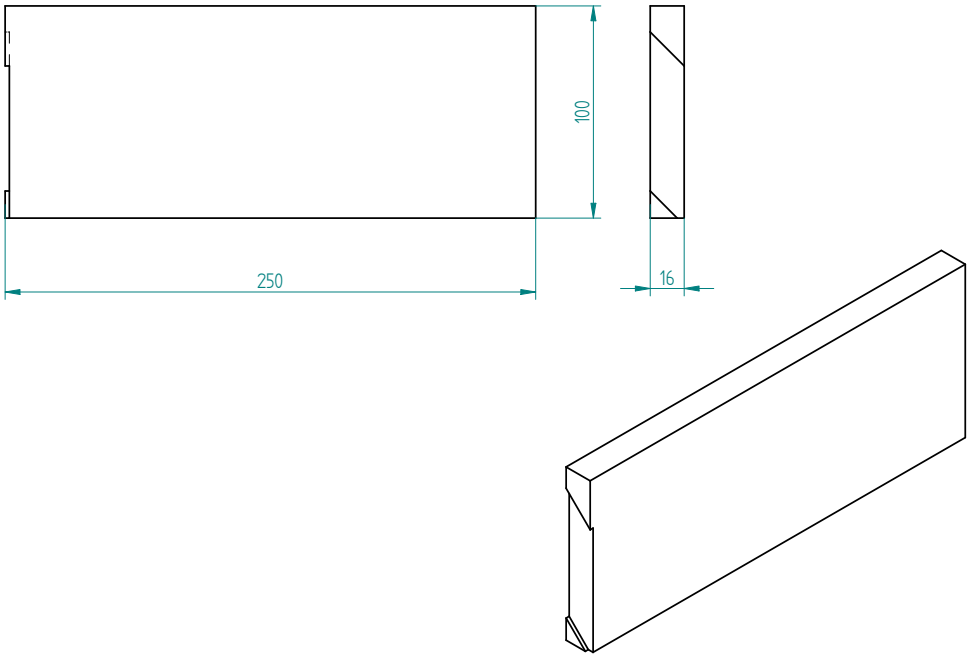


Figure A.5: Shaped part : **face-1** for **perpendiculator** tool

quantity 1 ;

material MDF ;

provider joinery ;

price ?.

face-2

Roadmap

1. order the part in a joinery see figure A.6, page 166 for dimensions ;

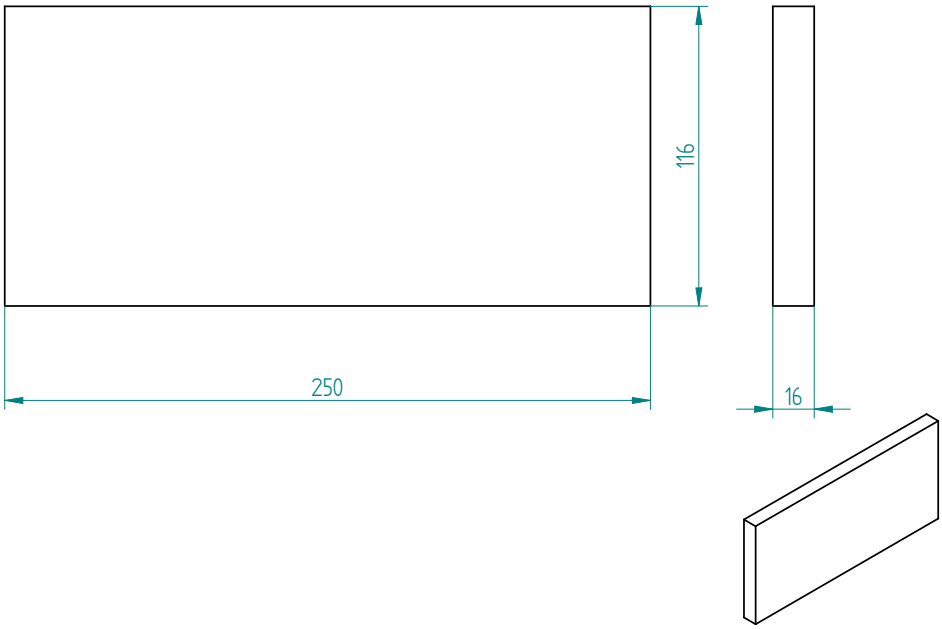


Figure A.6: Shaped part : **face-2-outsourcing** for **perpendiculator** tool

2. drill the holes for dimension of the hole and positions see figure A.7, page 167.

Drawing See figure A.7, page 167

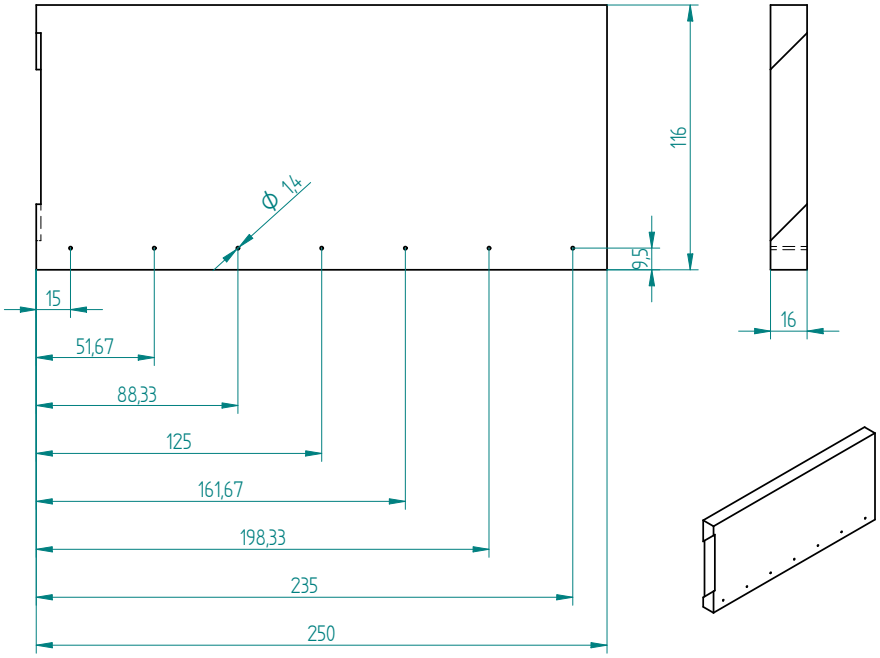


Figure A.7: Shaped part : **face-2** for **perpendiculator** tool

quantity 1 ;

material MDF ;

provider ironmongery ;

price ?.

A.1.5 Normalized parts

In this paragraph the normalized parts of the **perpendiculator** are showed. Like :

- **sandpaper** ;
- **nails**.

rectangular-wooden-list

Here are some information of the **rectangular-wooden-list** which are used to build the **perpendiculator**.

Drawing See figure A.8, page 168

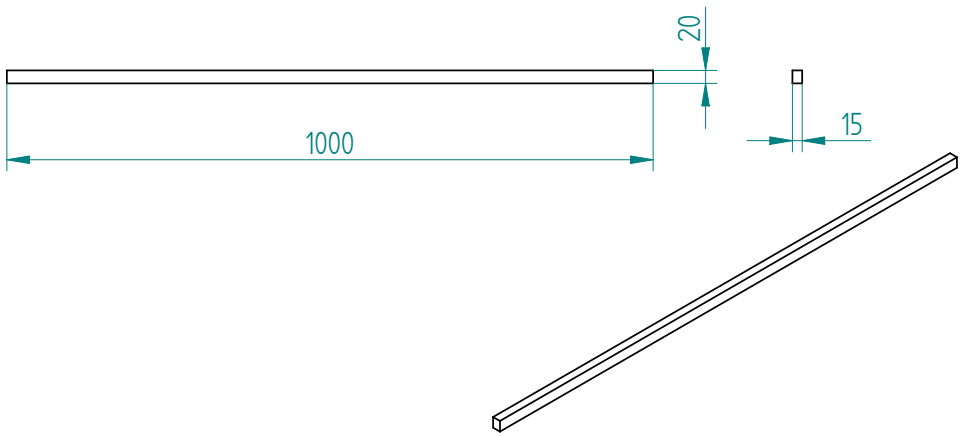


Figure A.8: Normalized part : **rectangular-wooden-list** for **perpendiculator** tool

quantity 1 ;

material beech ;

provider ironmongery ;

price 5.20frs.

sandpaper

Here are some information of the **sandpaper** which are used for the **perpendiculator**.

Size ? ;

Provider any ironmongery ;

Price ?

nails

Here are some information of the **nails** which are used to build the **perpendiculator**.

Drawing See figure A.9, page 169

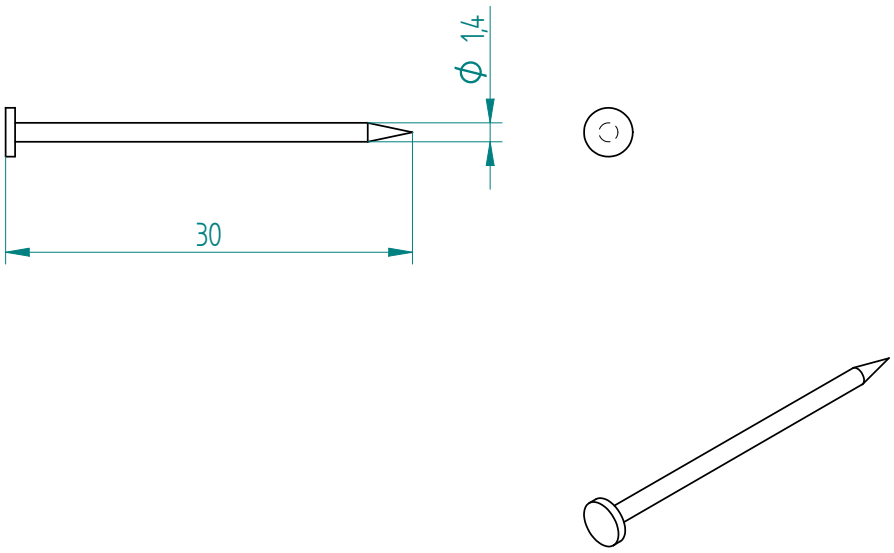


Figure A.9: Normalized part : **nail** for **perpendiculator** tool

quantity 1 box ;

material steel ;

provider ironmongery ;

price ?.

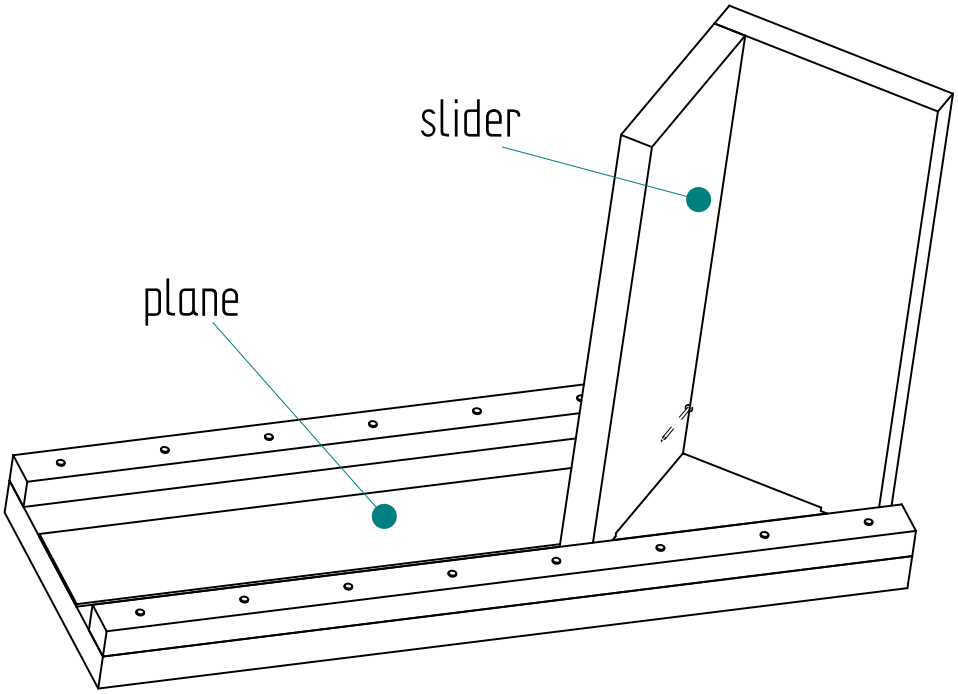
amidon-glue

quantity a bit ;

provider any ironmongery ;

price ?

A.1.6 Assemblies



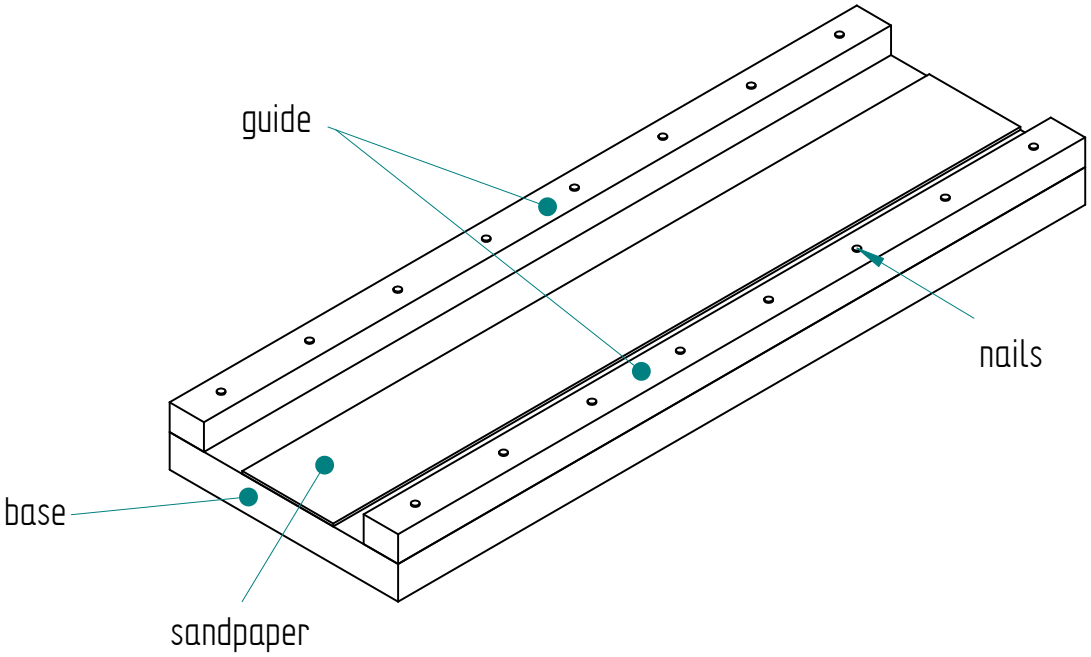
After built all the **Shaped-parts** and get all **Normalized-parts**, it's time now to assemble the sub-assemblies :

- **plane** ;
- **slider**.

Roadmap

1. assemble the **plane** ;
2. assemble the **slider** ;
3. assemble the **perpendiculator** with **plane** and **slider**.

plane



In this section we explain how to assemble the **plane** which is a sub-assemblie of the **perpendiculator**.

Worldmap

1. with **amidon glue** glue the **sandpaper** at the right position (see figure A.10, page 172) ;

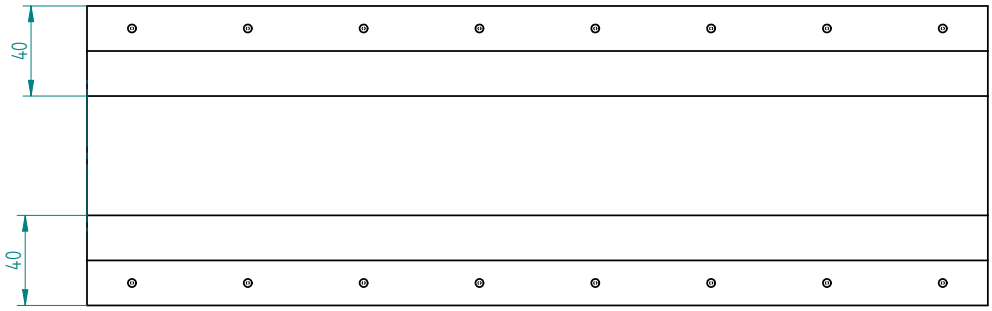
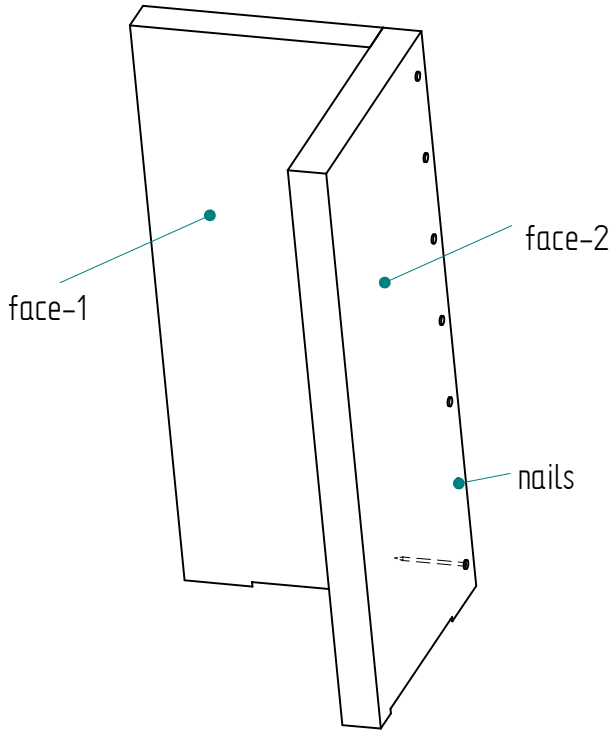


Figure A.10: position of the **sandpaper** on the **base**

2. align the **guide** to the edge of the **base** ;
3. once well aligned, **clamp** with two **clamps** ;
4. put the **nails** in the holes of the **guide** ;
5. hammer the **nails** maybe 2 or 3mm inside the **base** ;
6. make a mark to know the direction of **guide** on the **base** ;
7. remove the **clamps** and the **guide** from the **base** ;
8. put some **wooden glue** on the **guide** ;
9. then align the **guide** with the holes made with the **nails** in the **base** ;
10. hammer the **nails** deep into the **base** to tight the **guide** ;
11. repeat these steps for the second **guide** ;

slider



In this section we explain how to assemble the **slider** which is a sub-assemblie of the **perpendiculator**.

Worldmap

1. put the **nails** in the holes of **face-2** ;
2. align the **face-2** on the **face-1** ;
3. press both parts with a **clamp** ;
4. hammer the **nails** 3 to 4mm into the **face-1** ;
5. remove the **clamps** and unjoin **face-1** and **face-2** ;
6. put some **wooden-glue** on the **face-2** ;
7. join both part again taking care that that the **nails** go into the hole of 3 to 4mm depth done at the previous point ;
8. hammer the whole length of the **nails** so that both parts are pressed for glueing.

Appendix B

How to upload firmware

1. Install the **Arduino IDE** from `https://www.arduino.cc/en/software`.
2. In the Arduino IDE, go to **File** → **Preferences**, and in the "Additional Board Manager URLs", add:

   `https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_index.json`

3. Go to **Tools** → **Board** →¿ **Boards Manager**, search for `esp32`, and install the board package by `Espressif Systems`.
4. Connect your ESP32 board via USB and select the correct board from **Tools** → **Board**, e.g., `ESP32 Dev Module`.
5. Select the correct **COM port** under **Tools** → **Port**.
6. Open the firmware source code from the `code` directory.
7. Click the **Upload** button. If it fails to connect, press and hold the **BOOT** button on the ESP32 during the upload process.

Appendix C

Attach the motor cable

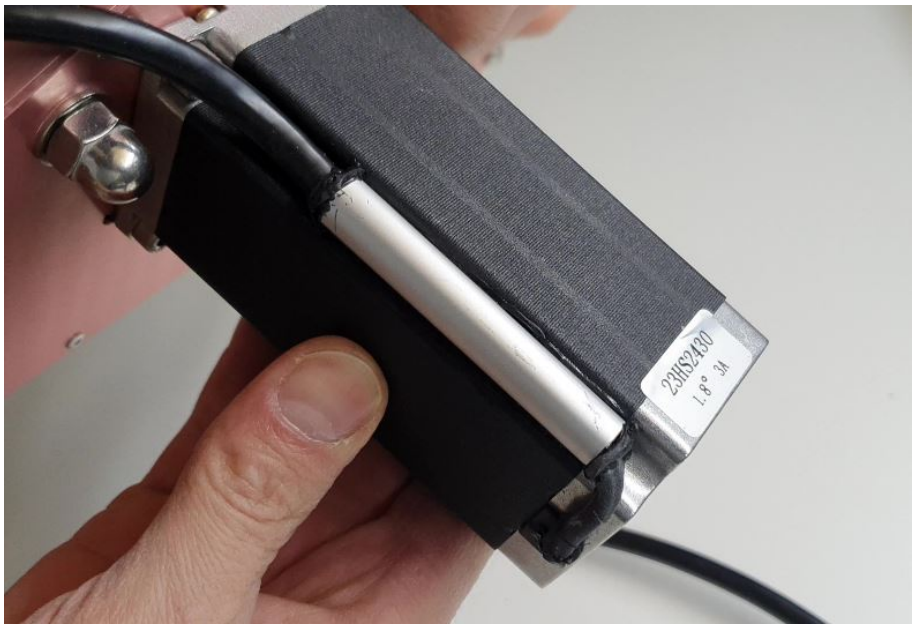


Figure C.1: motor cable attached

This appendix explains how to attach a motor cable to a motor that does not come with one pre-installed. While I do not recommend purchasing a motor without a pre-installed cable—since the final result often appears less professional. This method can be useful if a longer cable is required than what is typically provided.

A detailed walkthrough of the steps below is available in the following video :
`https://youtu.be/GfWPj4LcxXg`

1. Make an aluminium **tube** with the following dimensions: $10/8 \times 60\,\text{mm}$ (See Figure C.2, page 178).

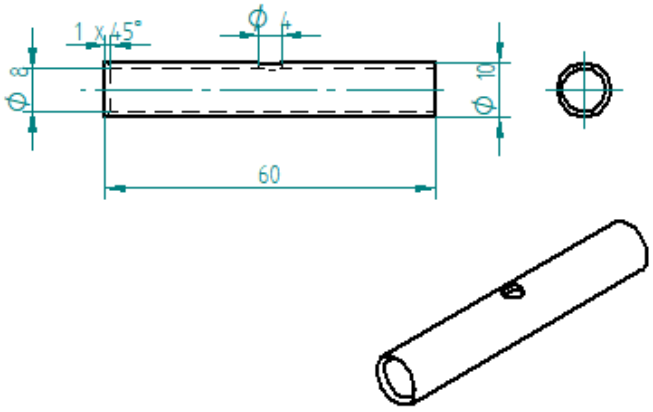


Figure C.2: motor cable tube

2. Unpack and test the motor. Connect the 4 wires to the **power unit** and make the motor rotate. This step is essential before proceeding with the remaining instructions.

   Remark: There are two types of motors: 3 A and 4.2 A. Each type uses different wire color codes. Depending on your motor's current rating, cut the wires as follows: (See also Figure C.3, page 179)

   - **Motor 3 A**:
     - Red wire: 47 mm
     - Yellow wire: 57 mm
     - Blue wire: 67 mm
     - Green wire: 77 mm
   - **Motor 4.2 A**:
     - Red wire: 47 mm
     - Green wire: 57 mm
     - Black wire: 67 mm
     - Blue wire: 77 mm

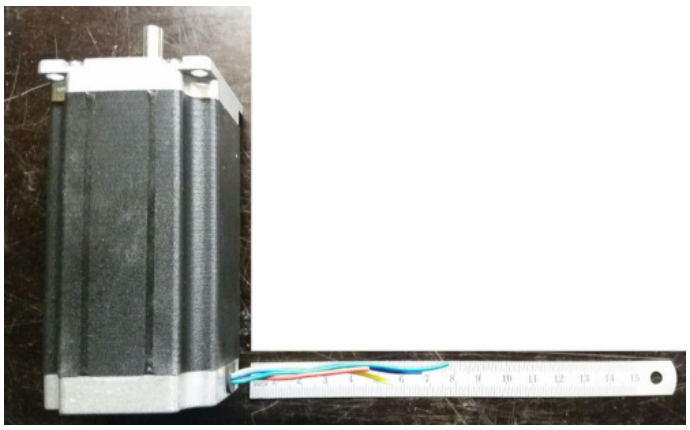


Figure C.3: motor cable wires lengths

3. Strip, twist, and tin-plate the motor wires over a length of 5 mm.
4. Cut a piece of heat shrink tube to 37 mm and tighten it using an industrial hot air gun. Ensure the red wire protrudes by approximately 5 mm.
5. Cut the 4-core silicone cable to a length of 2.2 m.
6. Strip the outer sheath of the 4-core silicone cable to a length of 45 mm.
7. Cut the inner wires of the 4-core silicone cable to the following lengths:
   - Red: 40 mm
   - Yellow: 30 mm
   - Black: 20 mm
   - Green: 10 mm
8. Strip, twist, and tin-plate each of the inner wires to a length of 5 mm.
9. Cut four pieces of heat shrink tube, each 13 mm long.
10. Slide the 13 mm heat shrink tubes and the cable holder tube onto the silicone cable. Pay attention to the orientation of the chamfer ($1 \times 45°$). Then solder the connections.
11. Degrease the cable holder tube, the silicone cable, and the motor using acetone.

    Warning for m1: If the **motor** is not yet fixed to the machine, remember to insert the screw into the motor's threaded hole (see picture below).
12. Inject silicone glue into the 4 mm diameter hole until it exits from both sides of the cable holder tube. Use any excess to seal around the motor groove where the M5 $\times$ 40 hex-head Allen screw is located. Rotate the cable holder so the injection hole is hidden against the motor. Install a cable tie around the silicone cable, and attach the cable holder using the clamp (See Figure C.4, page 180). If needed, inject more glue at the chamfered end of the tube and apply silicone on the motor to cover any wires that extend slightly beyond the heat shrink tubing.

Figure C.4: Clamp the tube in place during curing.

13. Allow the assembly to harden. Clean up and remove any glue residue or excess from the **tube**.