



UNIVERSIDAD DE CÓRDOBA

ESCUELA POLITÉCNICA SUPERIOR

DEGREE IN COMPUTER ENGINEERING
COMPUTER SPECIALIZATION

FINAL DEGREE PROJECT

Hardware modification of a 3D printer to make prints by means of using two extruders in parallel

User manual

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Part I

Introduction

Chapter 1

Introduction

This manual will explain in detail the modification, adaptation and assembly of the structure of a 3D printer. The printer employed for this manual is the **X400 CE** [1] by RepRap.

With this modification it is intended to obtain an adaptation of its structures. Thus, in the future it will be only necessary to modify its electronics and software. With these changes it is possible to obtain a 3D printer with double extruder for parallel printing.

NOTE: Some images and indications are taken out from the original manual of X400 CE by rereprap Germany [1].

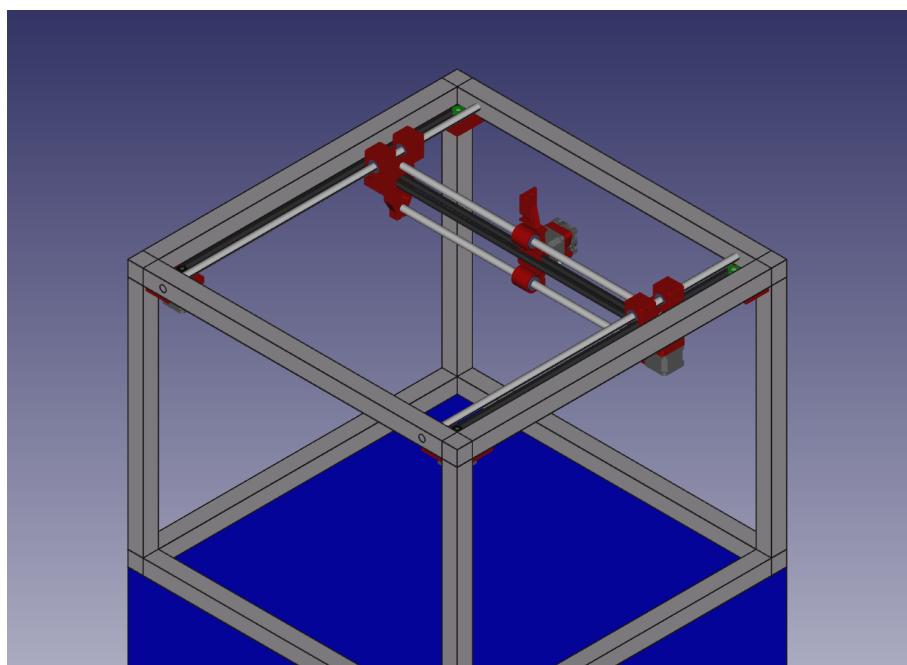


Figure 1.1: X400 CE original

The final model that is obtained is in the following image:

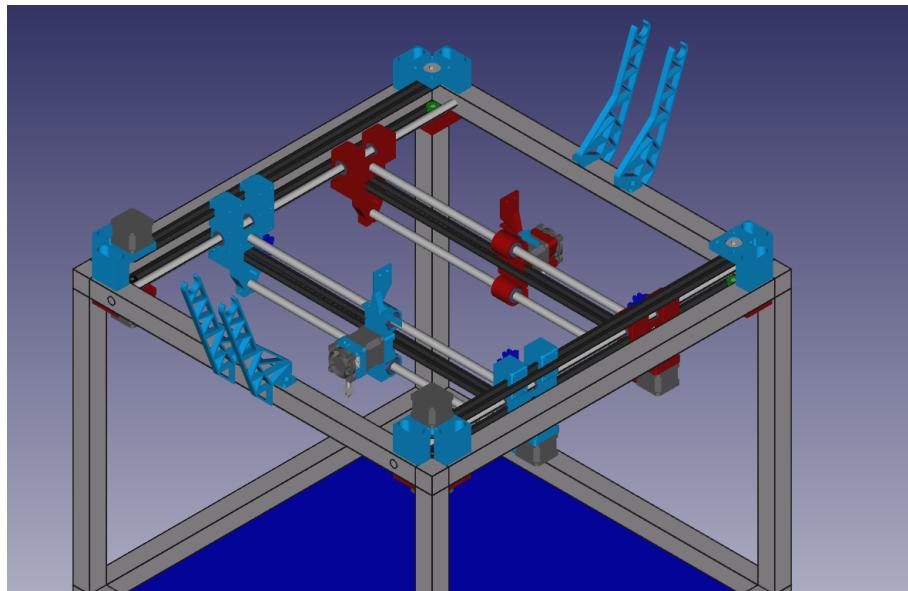


Figure 1.2: Modified X400 CE v1.0

Part II

Requirements

Chapter 2

Requirements

In this chapter all the parts that have been added to the model X400CE and those extra components, unprintable, needed to complete the structure of the 3D printer are described. It is made a division in printable, unprintable and finally, the electronics.

2.1 Printable parts

In this section are presented all the parts which can be printed in a 3D printer. The X-axis is described, then the Y-axis and finally some optional accessories that may improve its use.

2.1.1 X-Axis

The X-Axis consists of the following parts:

- Modified X-glider

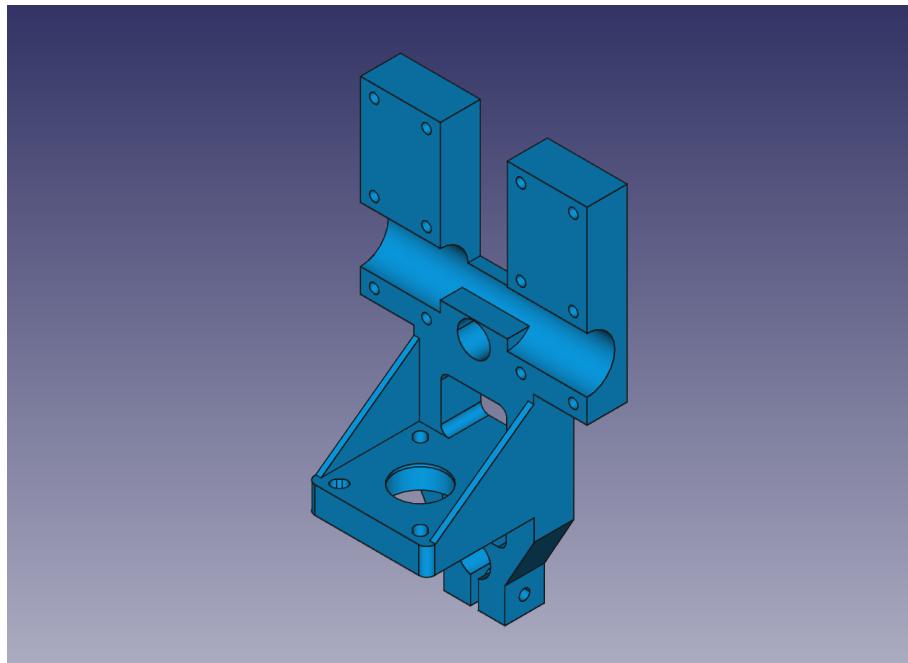


Figure 2.1: Modified X-glider

- Modified X-glider clamp LM12UU

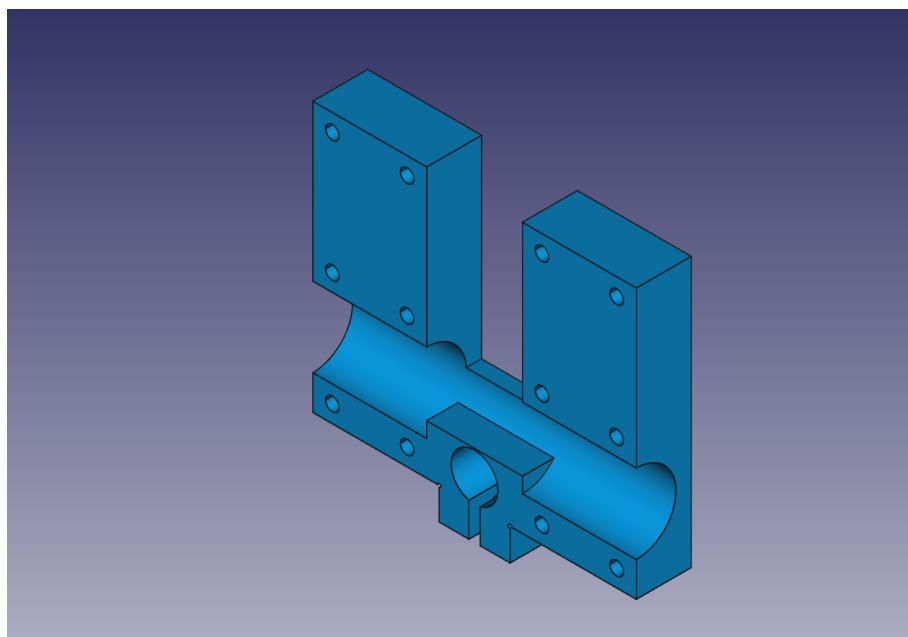


Figure 2.2: Modified X-glider clamp LM12UU

- Modified X-glider clamp belt

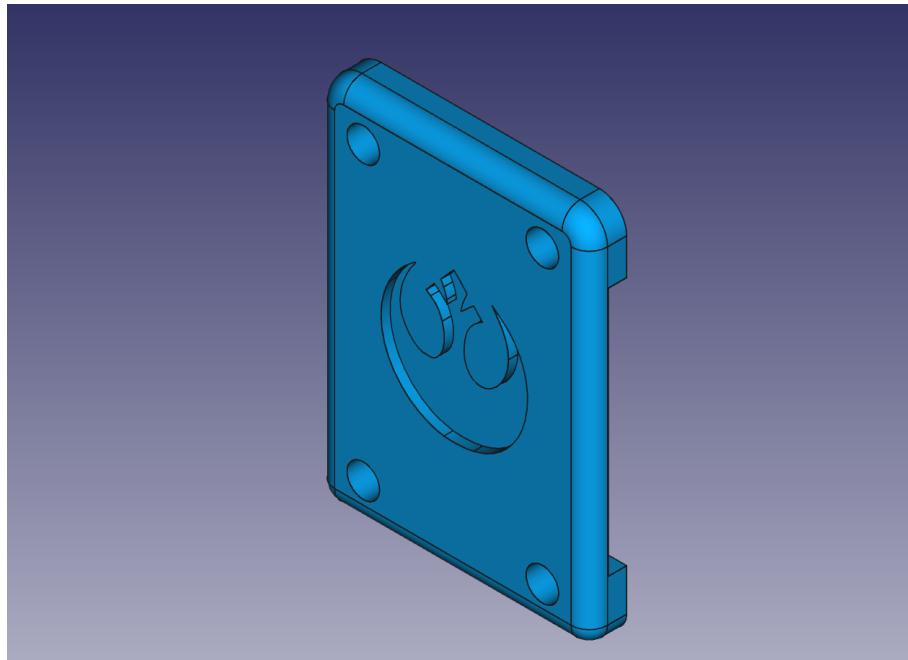


Figure 2.3: Modified X-glider clamp belt

2.1.2 Y-Axis

The Y-Axis consists of the following parts:

- Modified POM NEMA 17 Mount

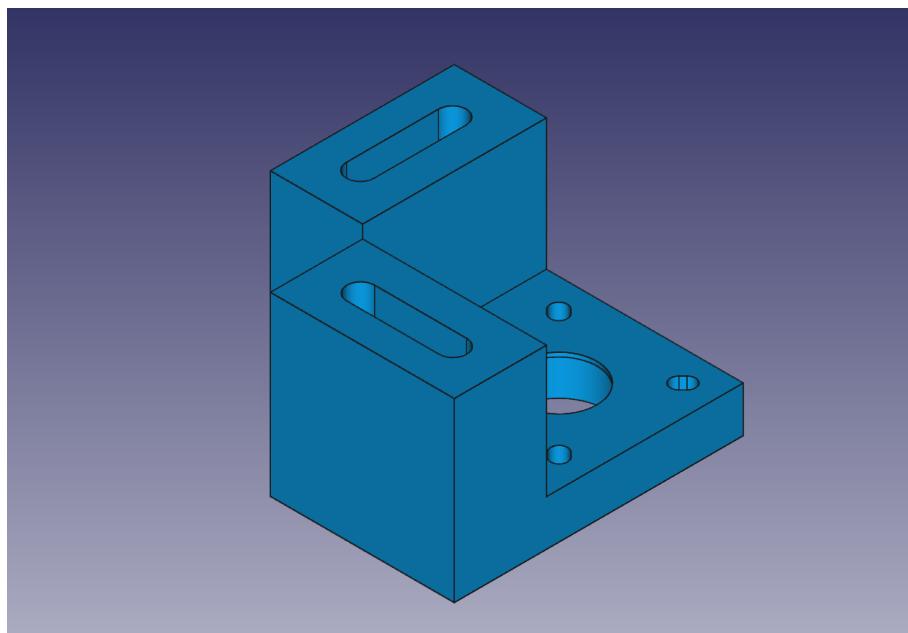


Figure 2.4: Modified POM NEMA 17 Mount

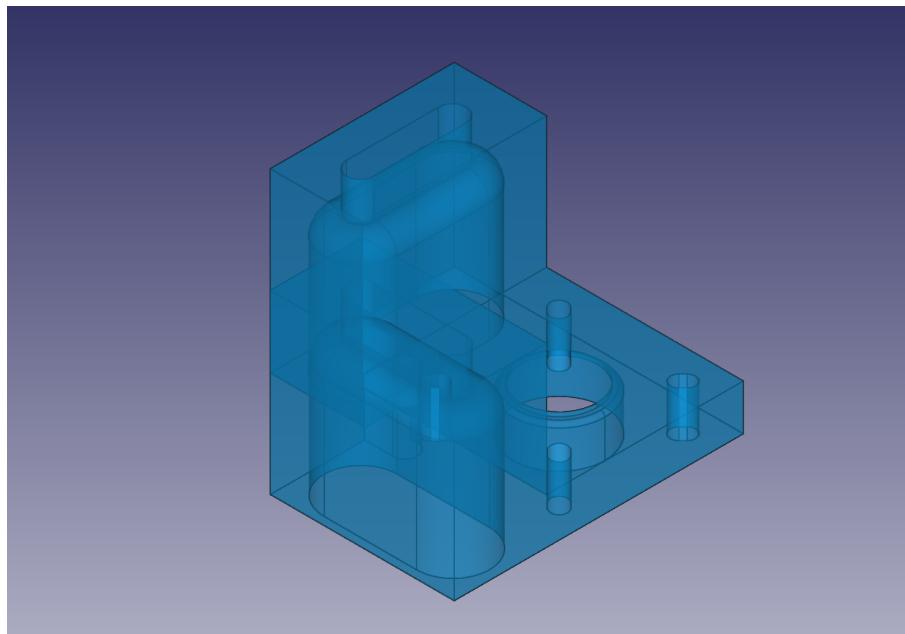


Figure 2.5: Modified POM NEMA 17 Mount

2.1.3 Extruder

Extruder support

The extruder support was designed by RepRap Germany. The developed pieces are a recreation of the original model. The extruder support consists of the following parts:

- **Carriage Cablemount**

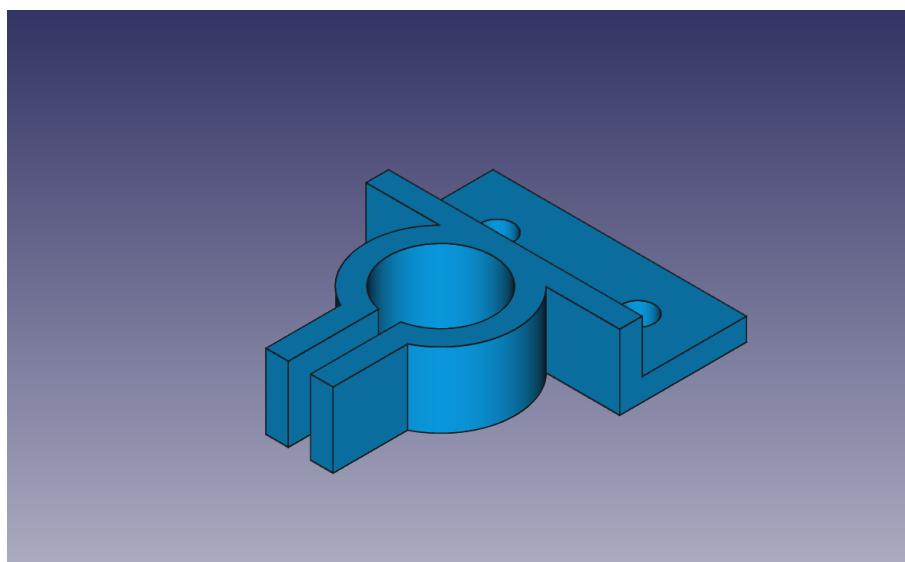


Figure 2.6: Carriage Cablemount

- Activator X-Axis End-stop

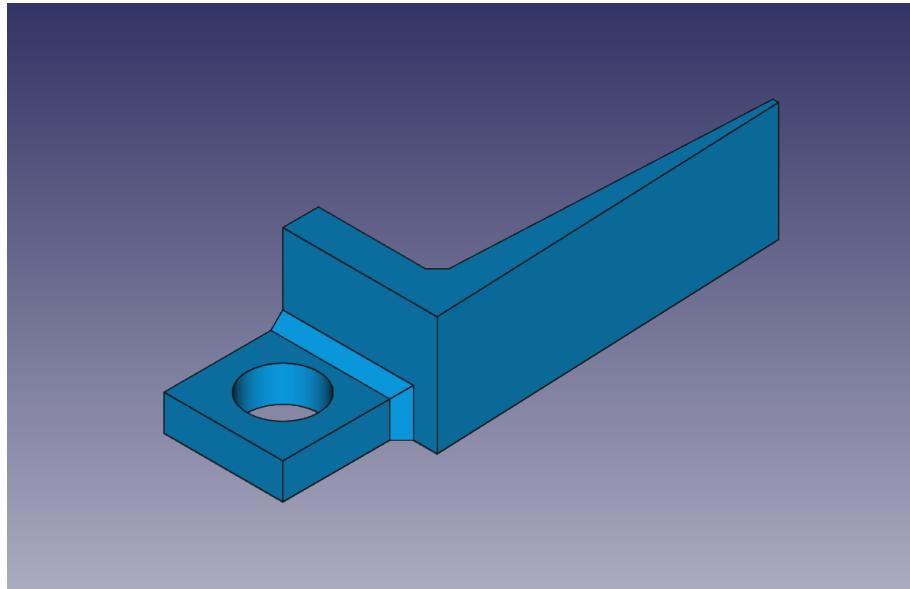


Figure 2.7: Activator X-Axis End-stop

- Carriage Clamp LM12UU

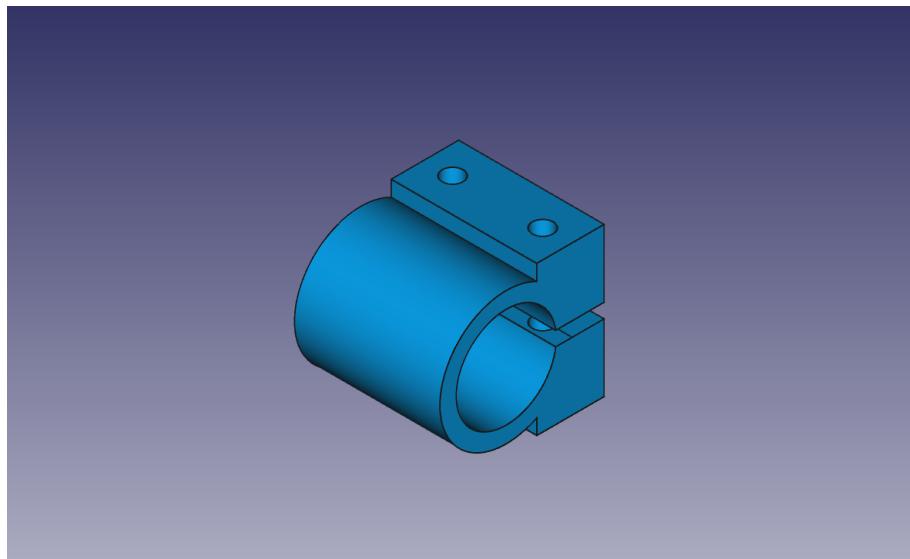


Figure 2.8: Carriage Clamp LM12UU

- **Carriage Fanmount**

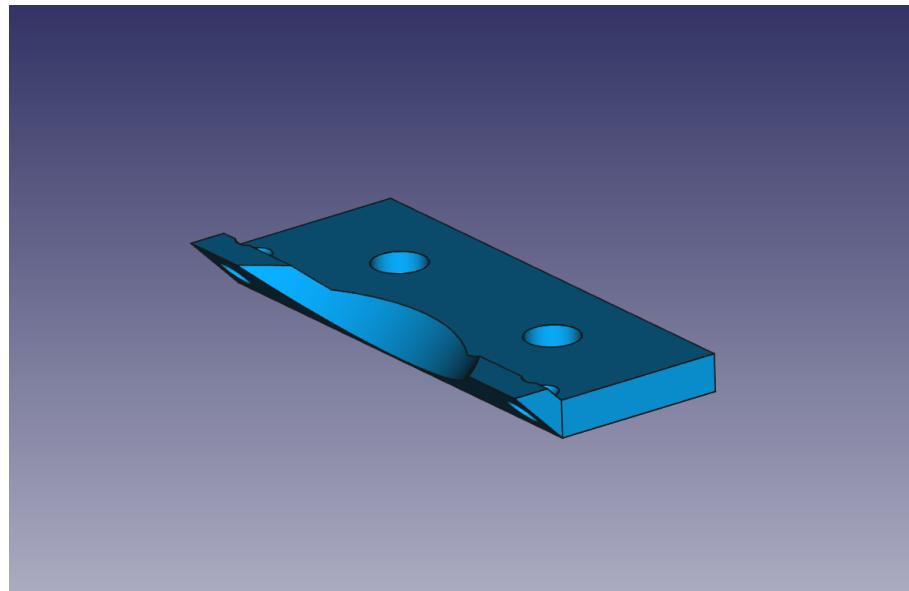


Figure 2.9: Carriage Fanmount

- **Carriage Mount**

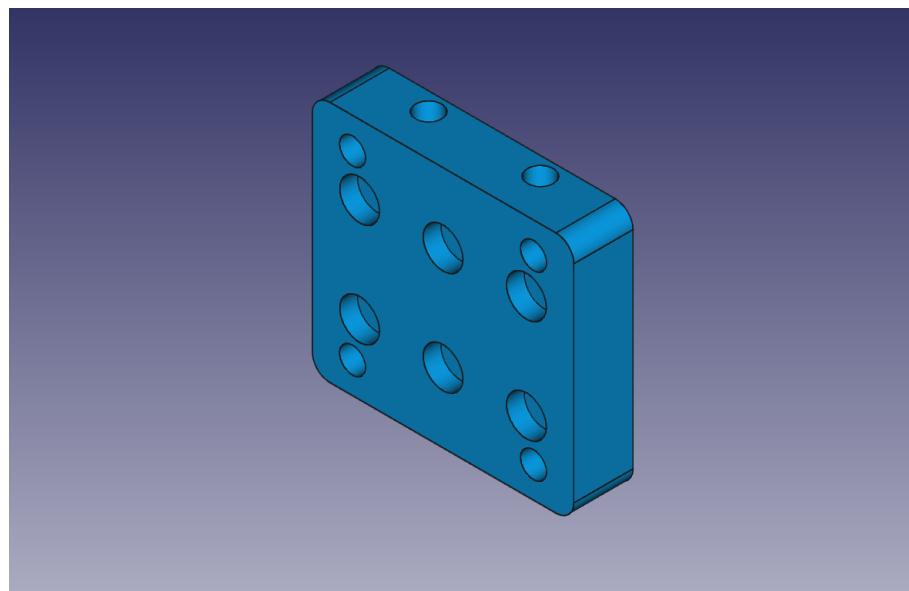


Figure 2.10: Carriage Mount

- Carriage Clamp Belt

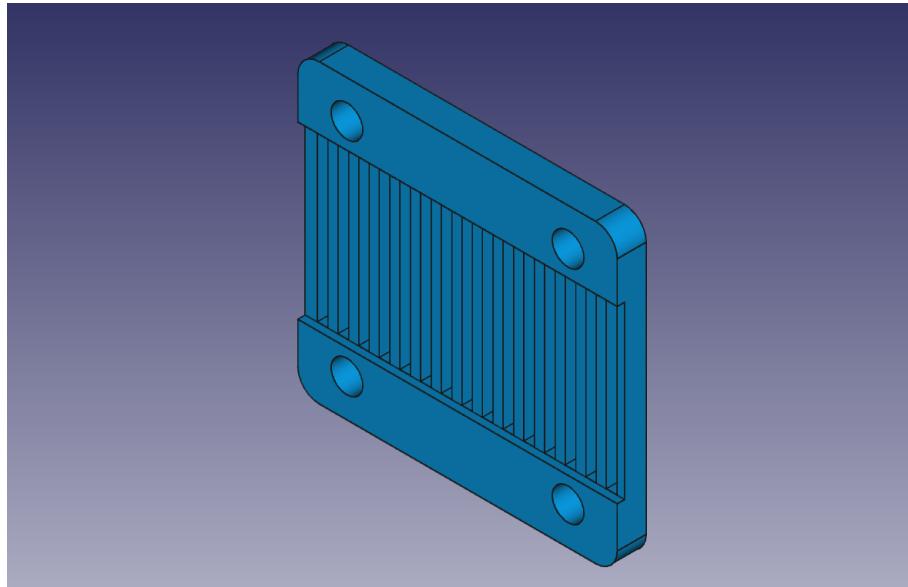


Figure 2.11: Carriage Clamp Belt

Extruder filament support

The extruder filament support was designed by *infinityplusplus* [2]. It consists of the following parts:

- Front piece ver.3

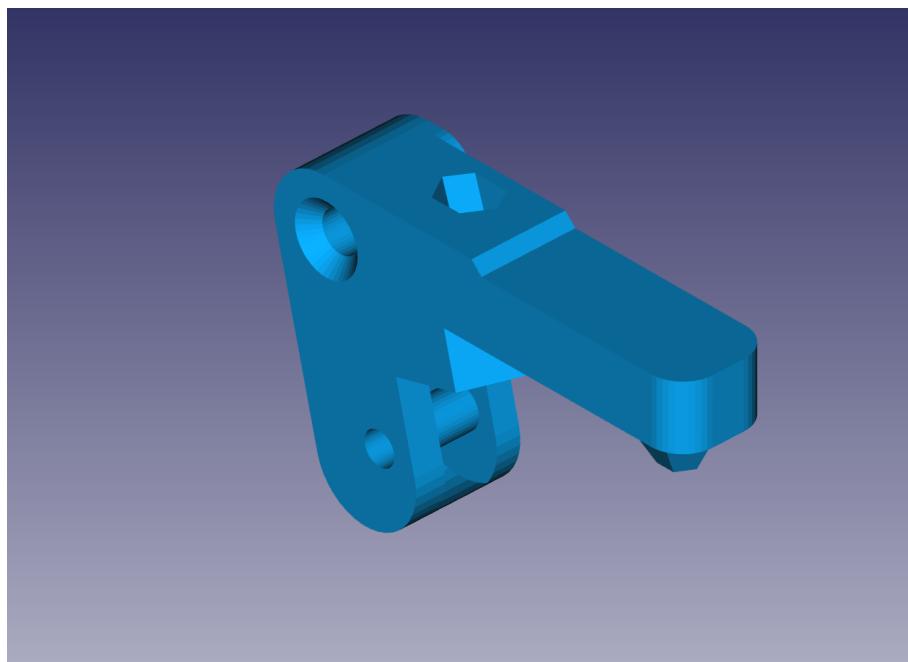


Figure 2.12: Extruder counter bearing, front part

- Back piece ver.2

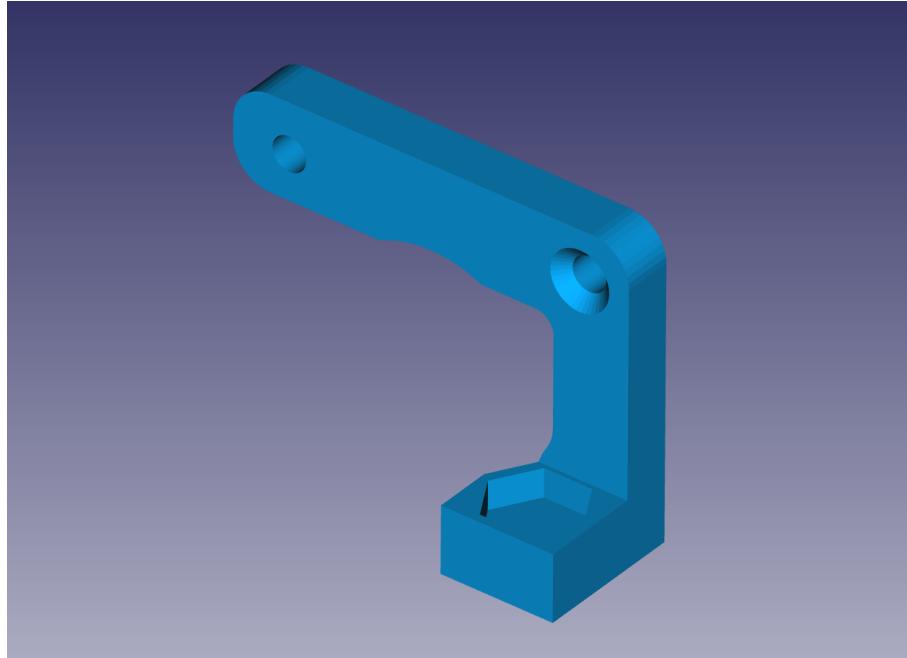


Figure 2.13: Extruder counter bearing, back part

2.1.4 Add-ons

These accessories are optional because they do not affect directly to the normal operation of the 3D printer and can be replaced by others. The accessories consist of the following parts:

- Filament support

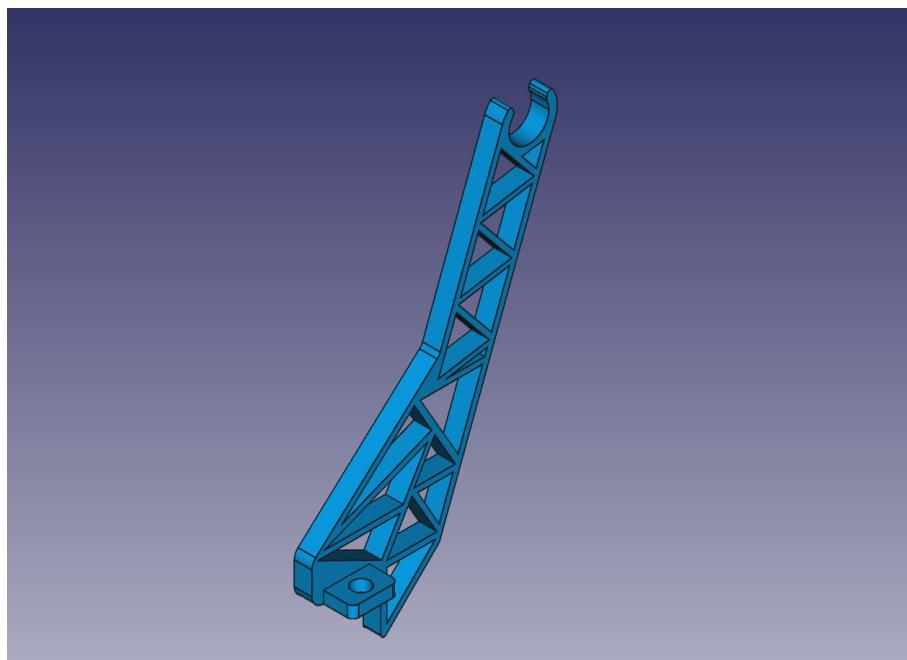


Figure 2.14: Filament support part Left

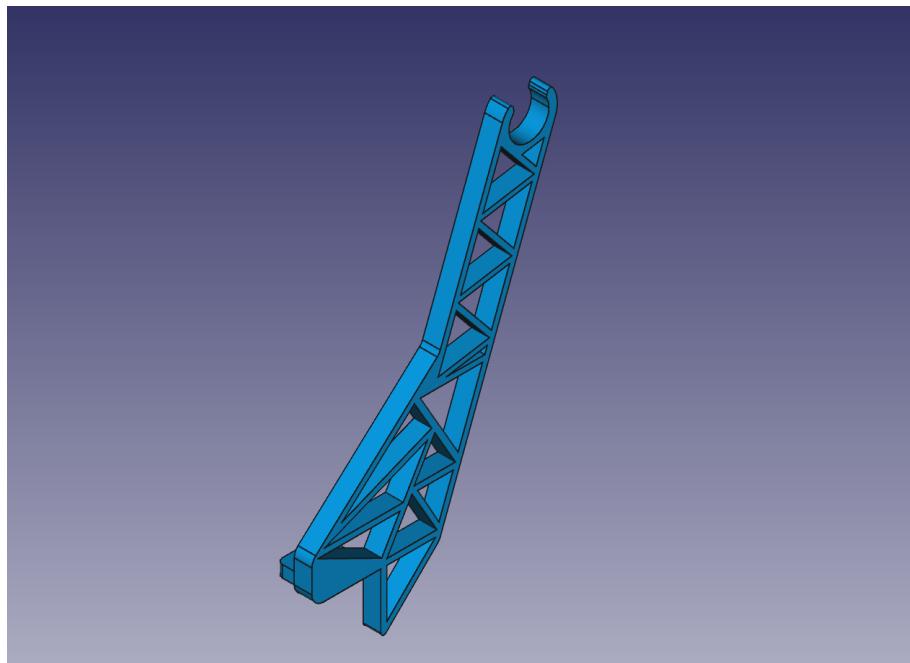


Figure 2.15: Filament support part Right

- **Pulley 16 - M8**

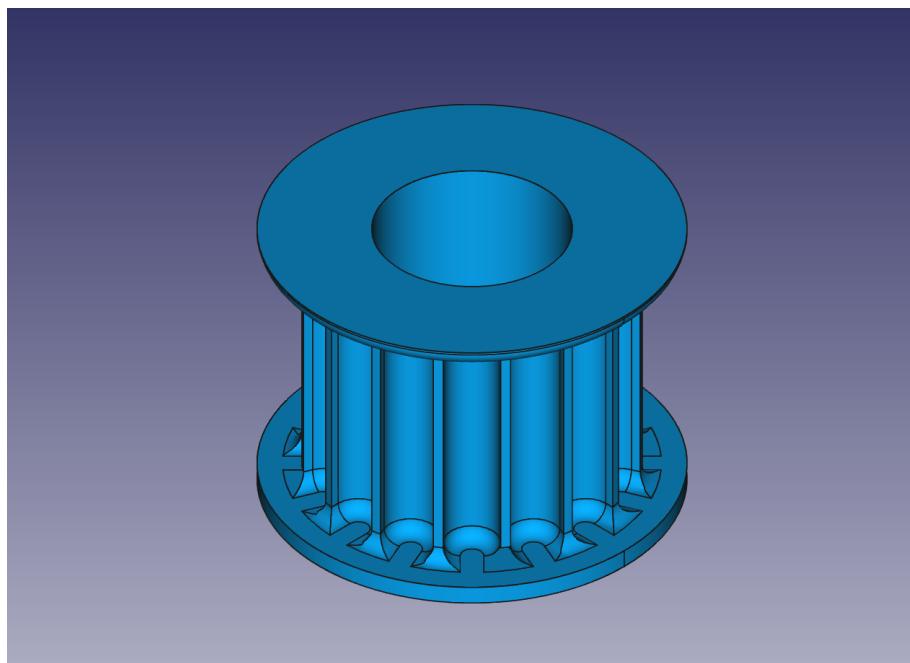


Figure 2.16: Pulley 16-M8

- **Cabling Support**

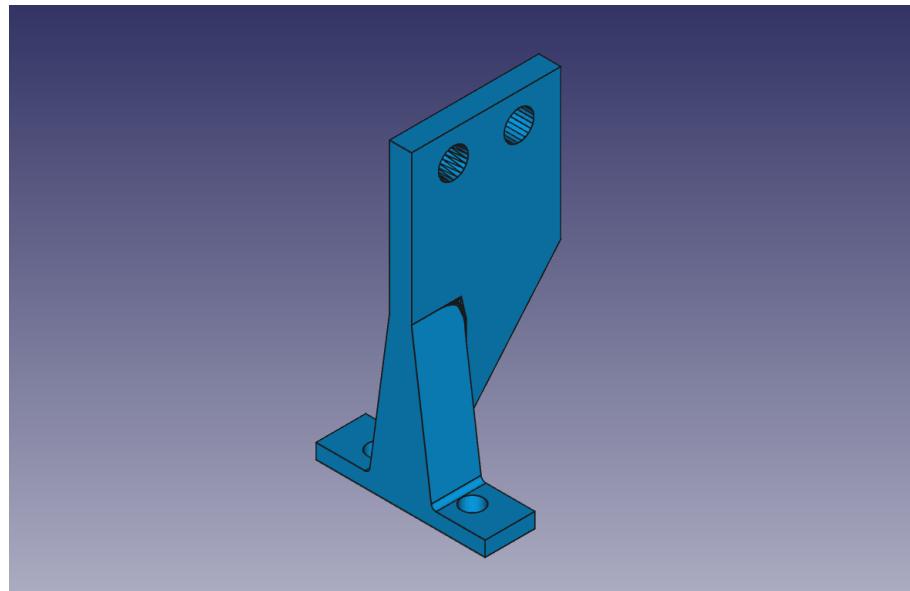
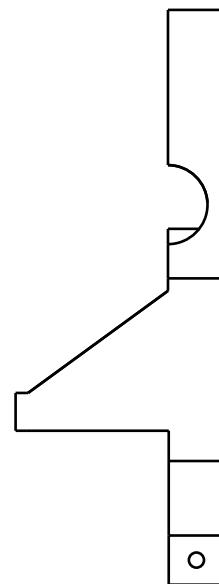
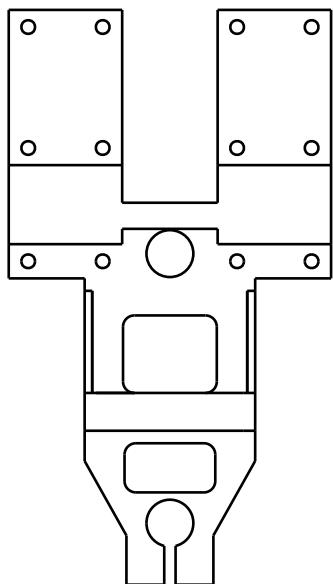
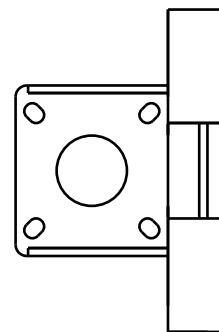
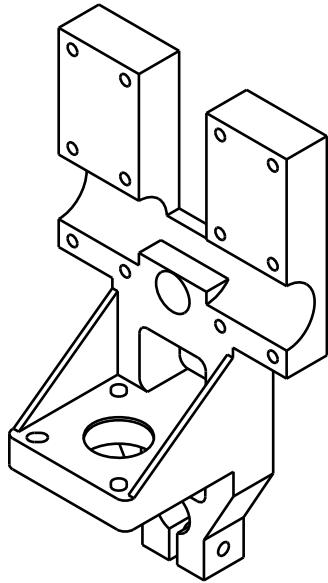


Figure 2.17: Cabling Support

2.1.5 Plans



Created by:

Antonio Jurado Caballero

Title:

X-glider Modified

Supplementary information:

FINAL DEGREE PROJECT: Hardware modification
of a 3D printer to make prints by means of
using two extruders in parallel

Size:

A4

Sheet:

X / Y

Scale:

1:2

Part number:

v 1.0.

Drawing number:

1

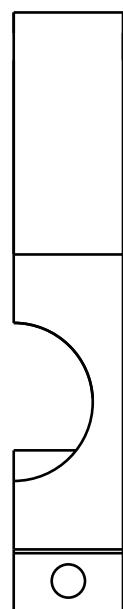
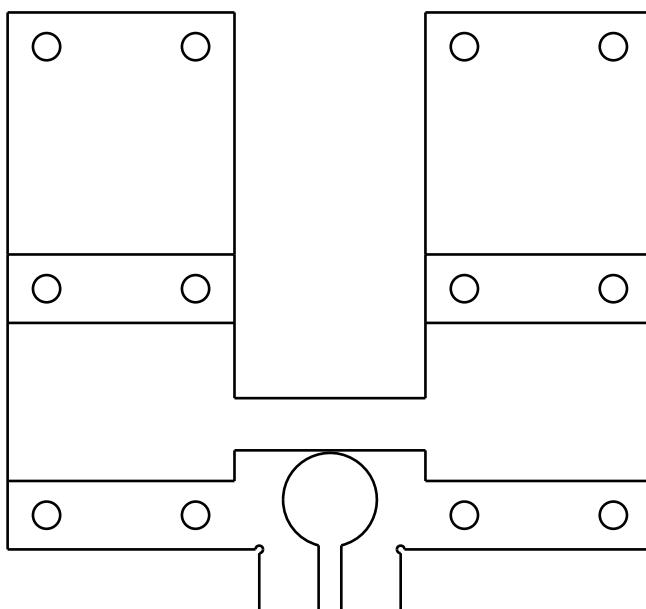
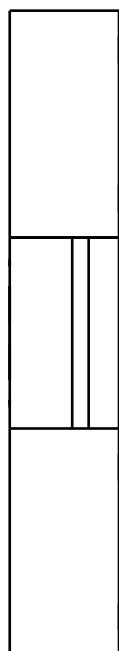
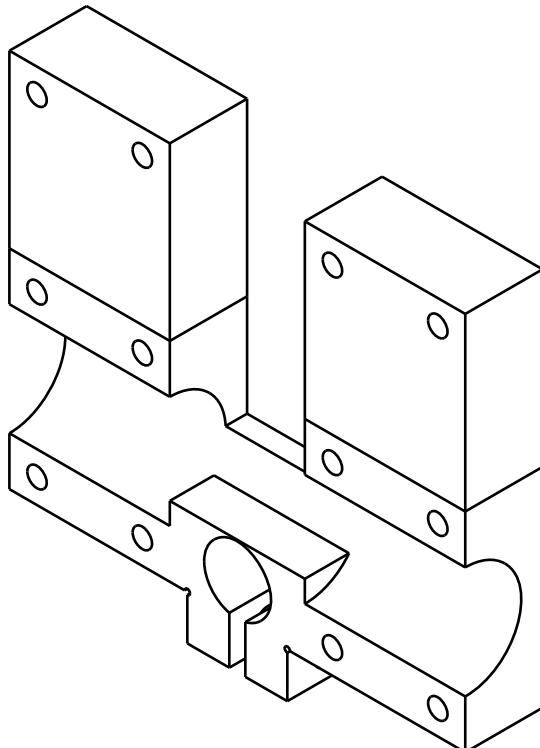
Date:

01/06/2016

Revision:

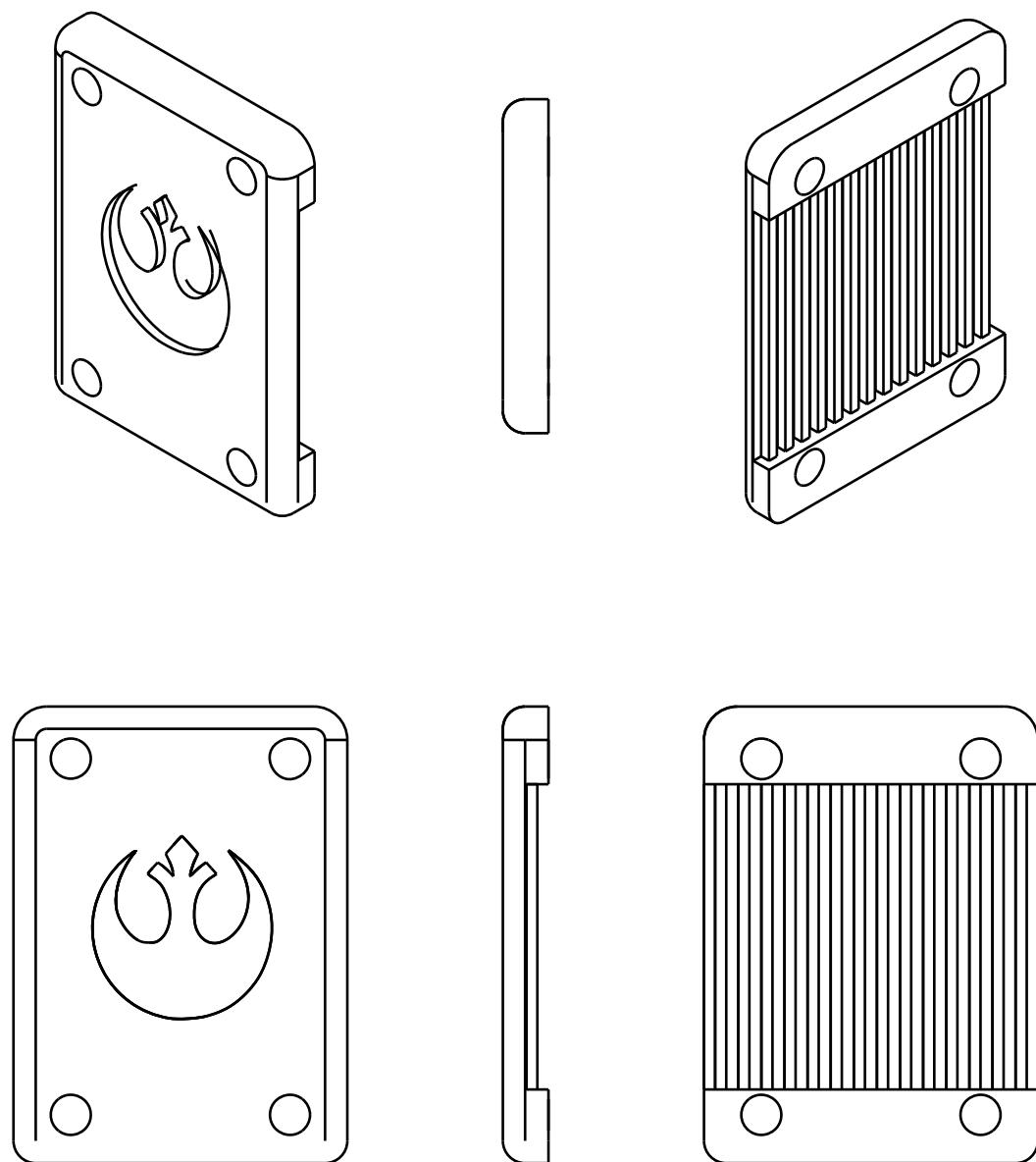
REV A



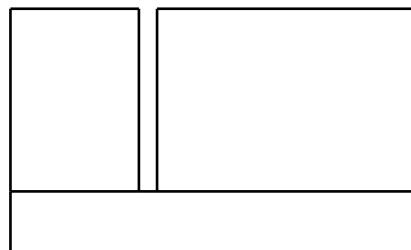
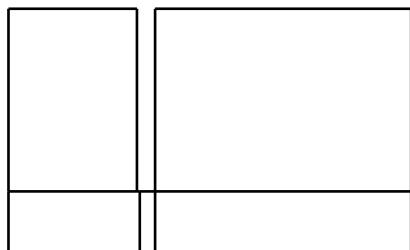
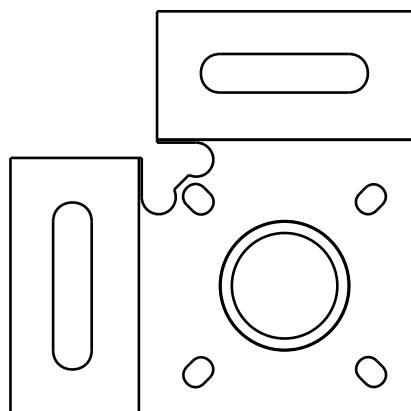
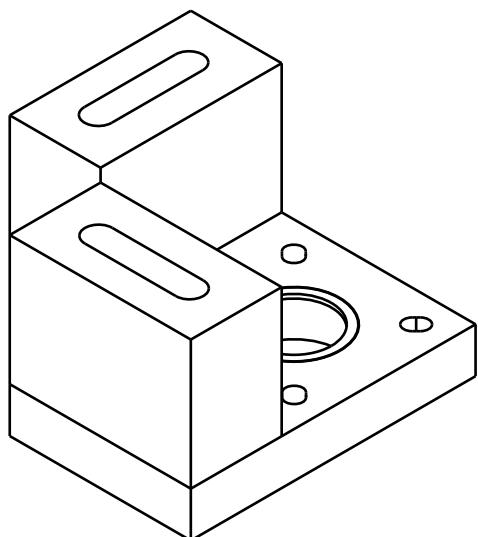


Created by: Antonio Jurado Caballero	Title: X-glider clamp LM12UU Modified	
Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4	Sheet: X / Y
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	Part number: v 1.0.	
	Drawing number: 2	
	Date: 01/06/2016	Revision: REV A



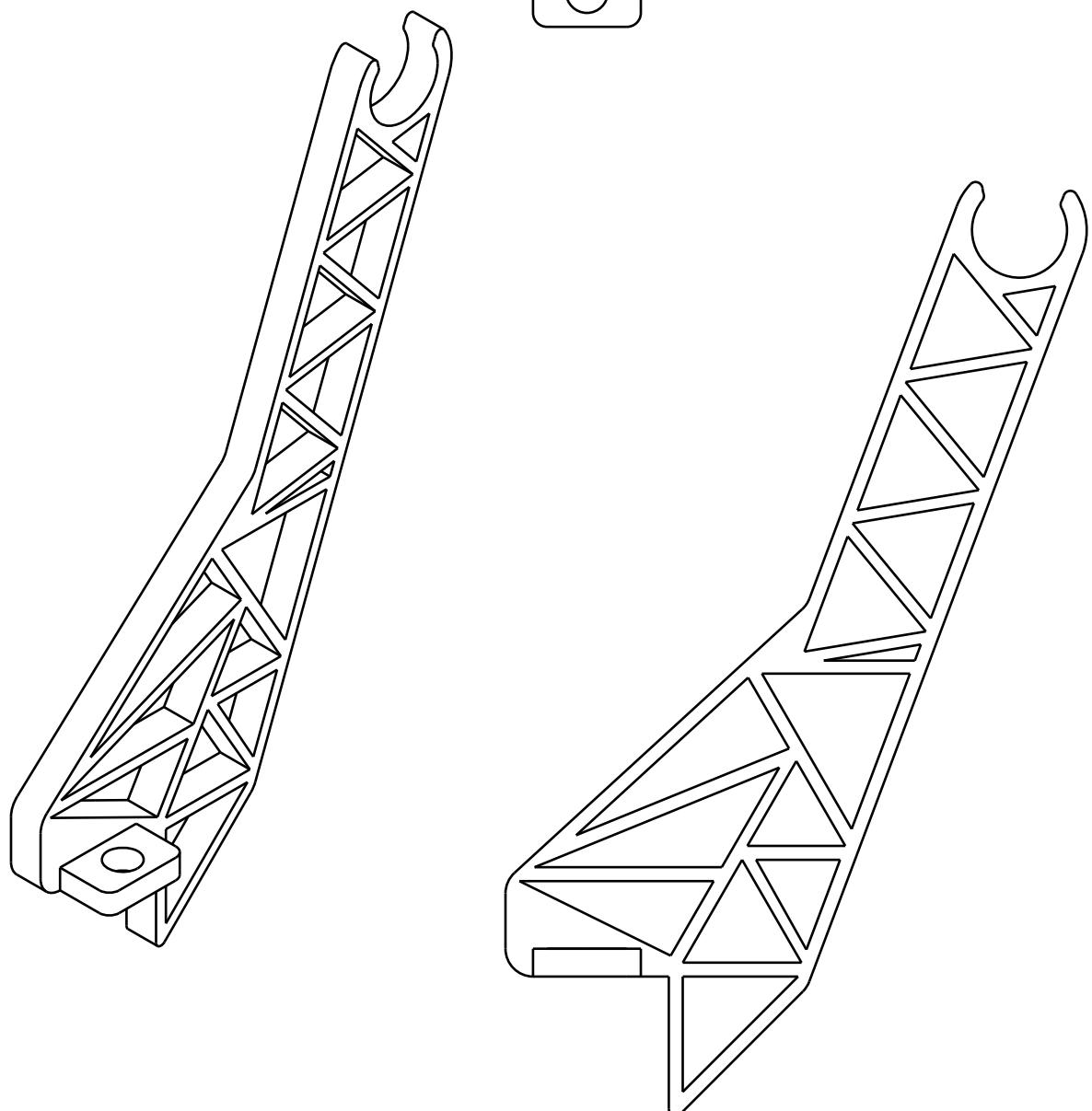


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Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4	Sheet: X / Y	Scale: 2:1
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	Drawing number: 3		
	Date: 01/06/2016	Revision: REV A	

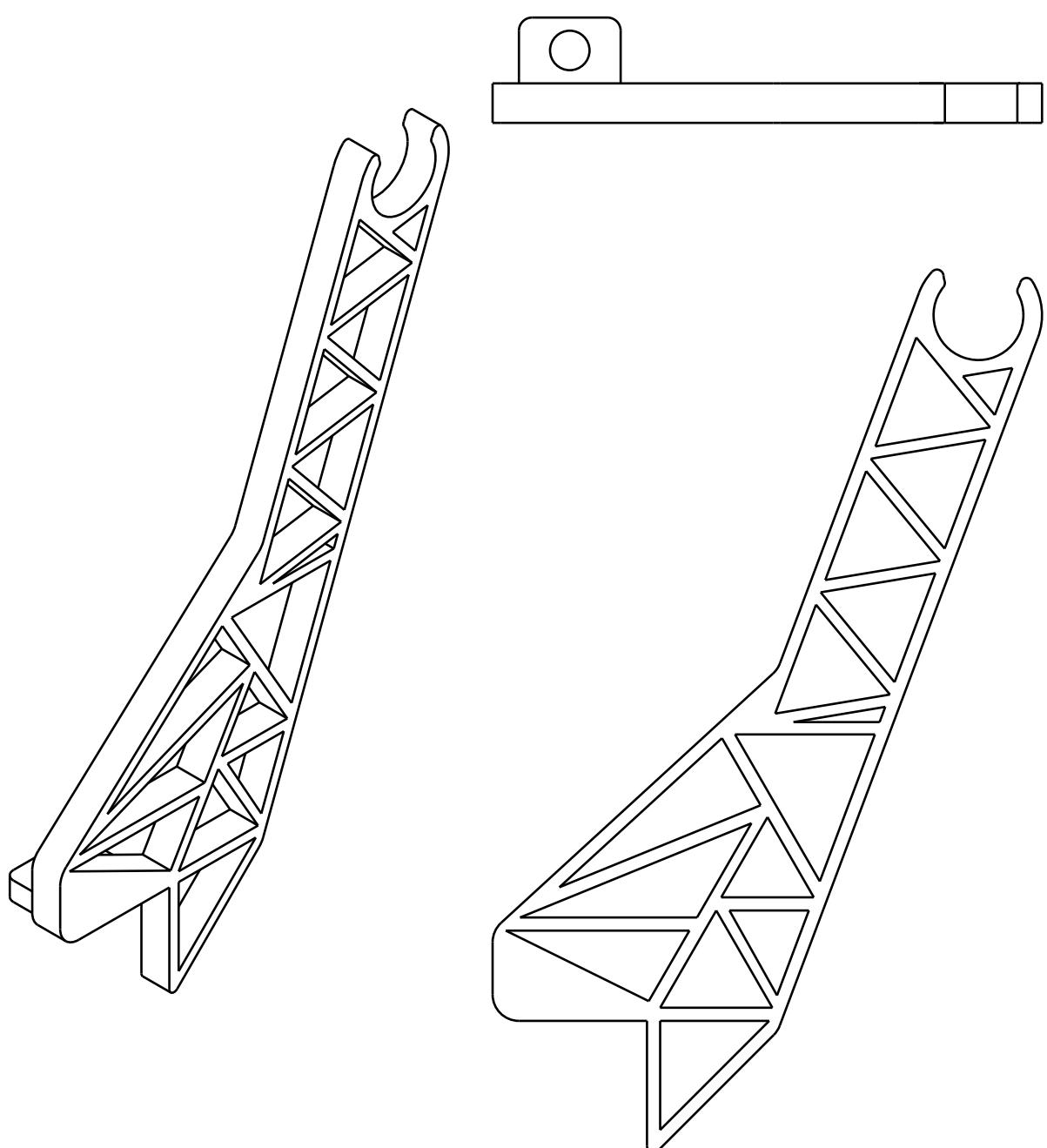


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Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4	Sheet: X / Y
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		Drawing number: 4
	Date: 01/06/2016	Revision: REV A

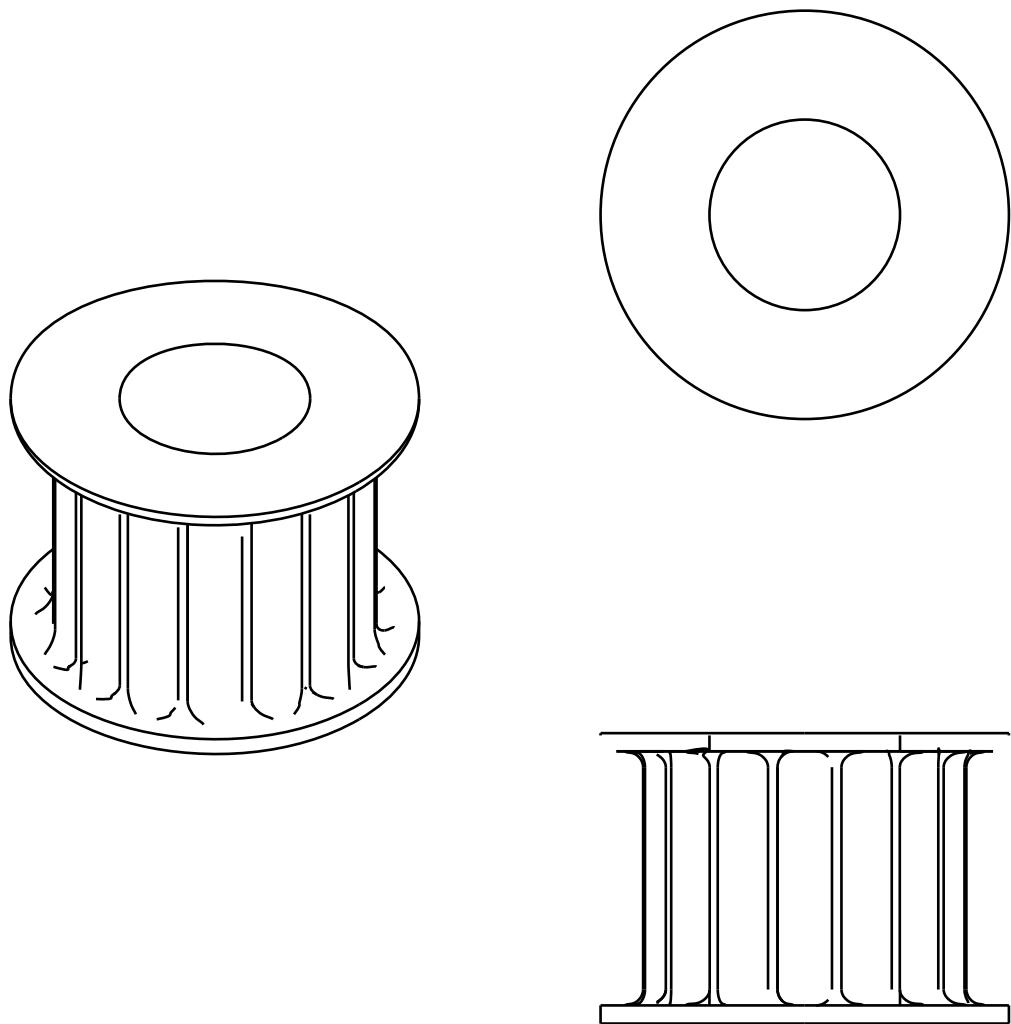




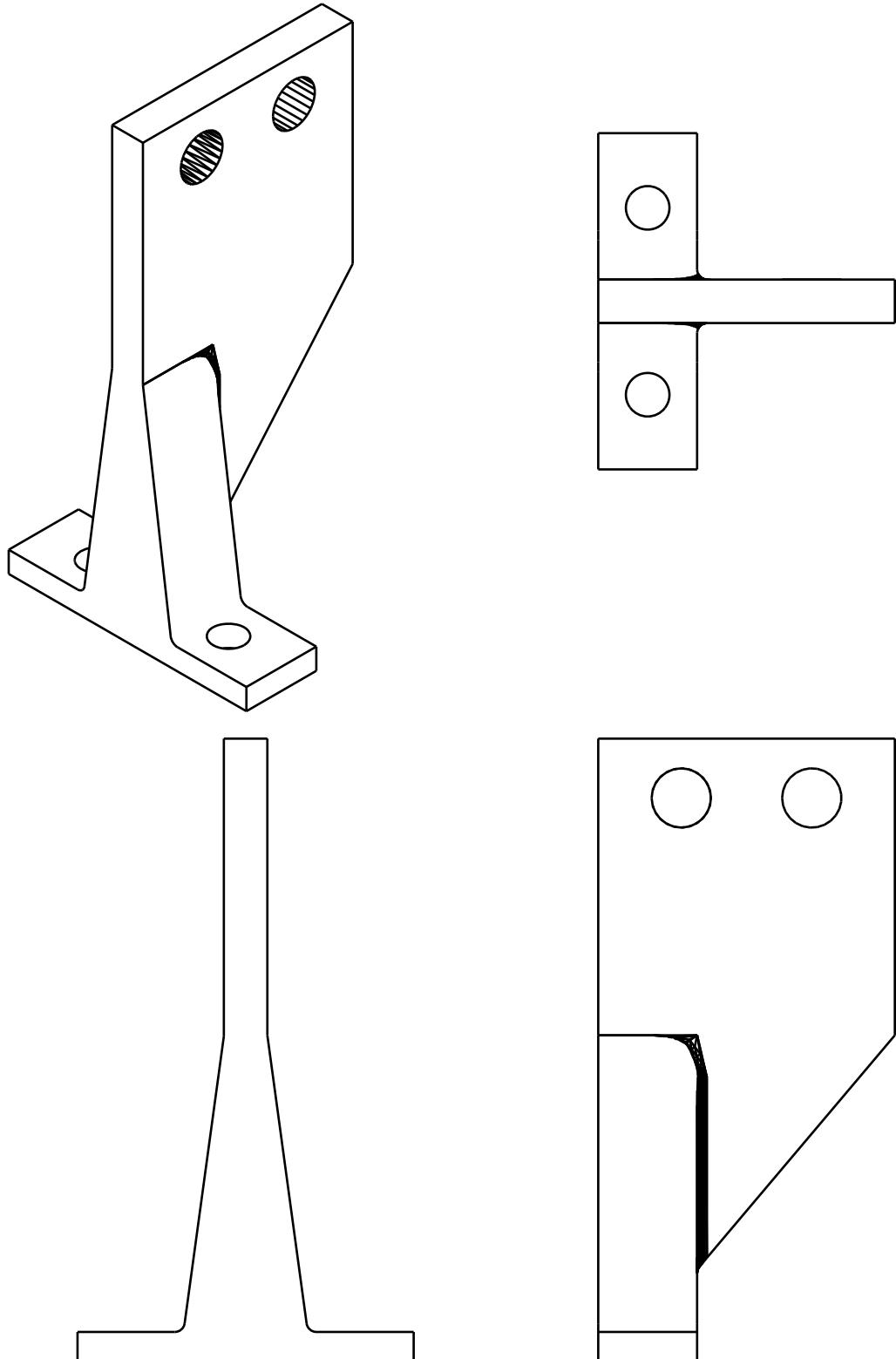
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Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4 Sheet: X / Y Scale: 1:2
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	Drawing number: 5
	Date: 01/06/2016 Revision: REV A



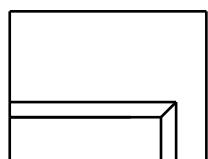
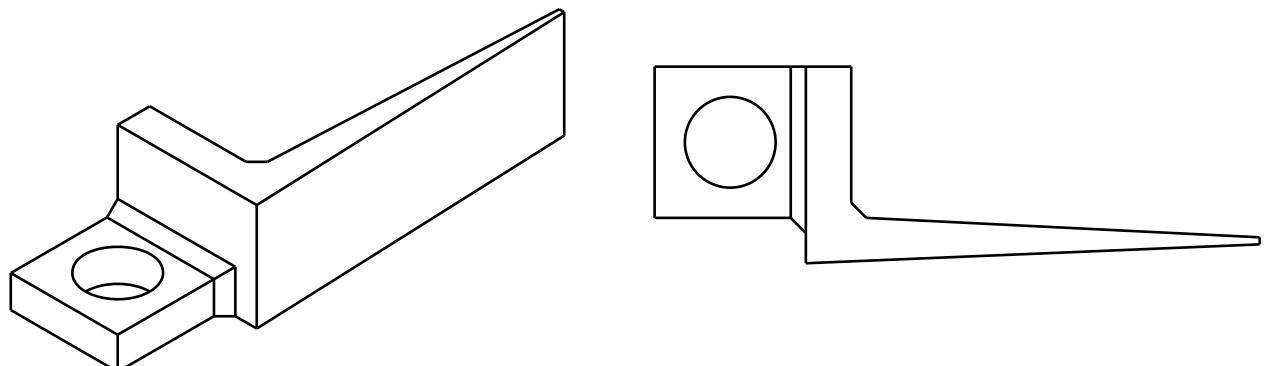
Created by: Antonio Jurado Caballero	Title: Filament suport right part
Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel	Size: A4 Sheet: X / Y Scale: 1:2
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	Drawing number: 6
	Date: 01/06/2016 Revision: REV A



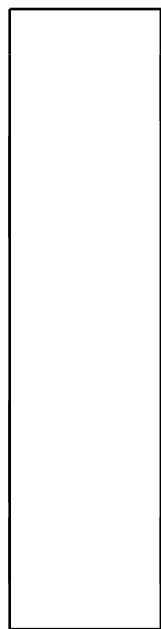
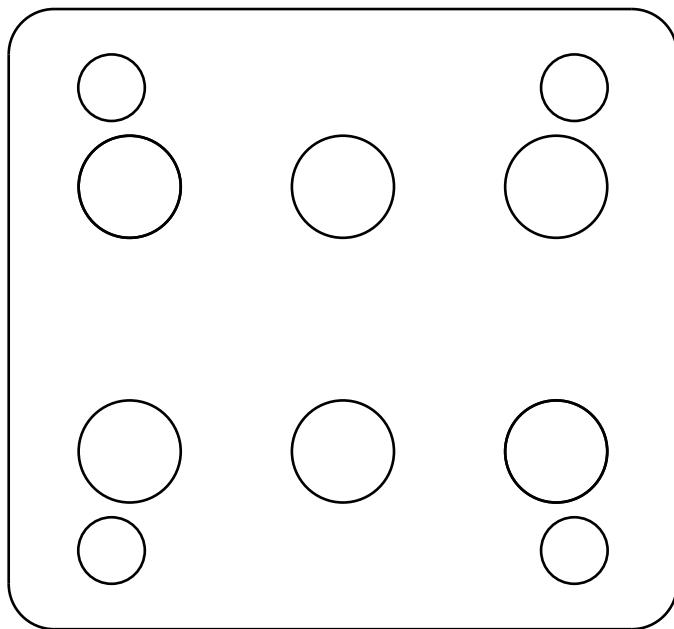
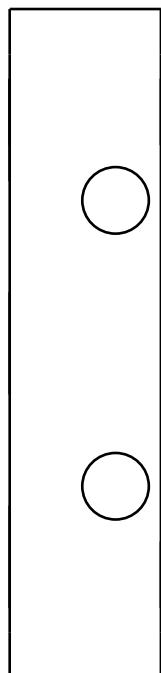
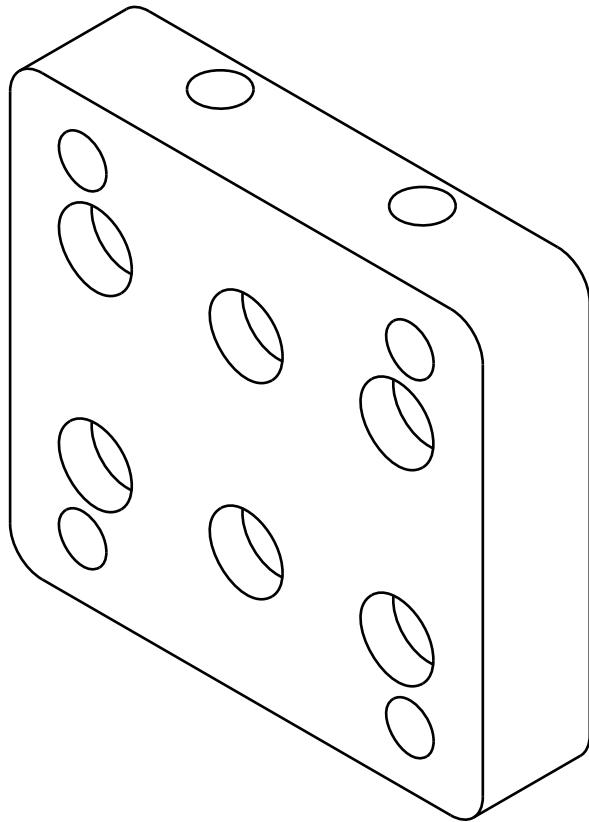
Created by: Antonio Jurado Caballero	Title: Polea 16 - M8	
Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4	Sheet: X / Y
	Scale: 3:1	
	Part number: v 1.0.	
	Drawing number: 7	
	Date: 01/06/2016	Revision: REV A



Created by: Antonio Jurado Caballero	Title: Cabling Support	
Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4	Sheet: X / Y Scale: 1:1,50
	Part number: v 2.0.	
	Drawing number: 8	
	Date: 01/06/2016	Revision: REV A



Created by: Antonio Jurado Caballero	Title: Activator X-Axis End-stop
Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4 Sheet: X / Y Scale: 2:1
	Part number: v 1.0.
	Drawing number: 9
	Date: 01/06/2016 Revision: REV A



Created by:

Antonio Jurado Caballero

Title:

Carriage Mount

Supplementary information:

FINAL DEGREE PROJECT:

Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.

Size:

A4

Sheet:

X / Y

Scale:

2:1

Part number:

v 1.0.

Drawing number:

10

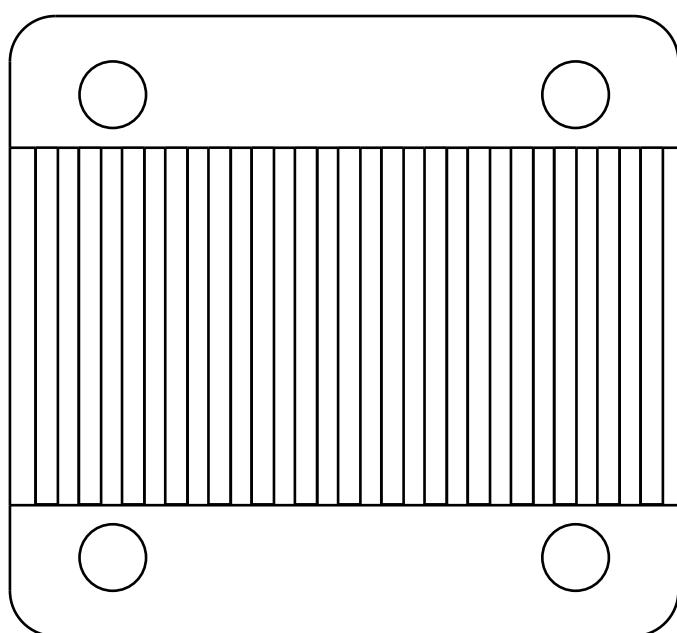
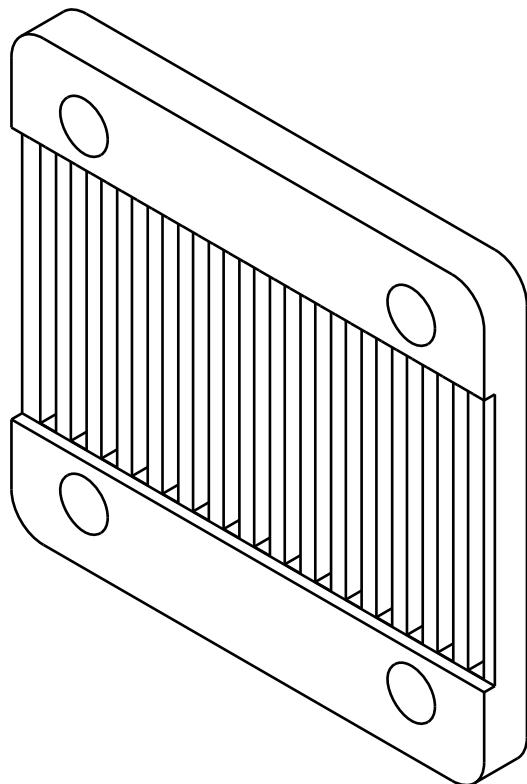
Date:

01/06/2016

Revision:

REV A





Created by:

Antonio Jurado Caballero

Title:

DRAWING TITLE

Supplementary information:

FINAL DEGREE PROJECT:

Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.

Size:

A4

Sheet:

X / Y

Scale:

2:1

Part number:

v 1.0.

Drawing number:

11

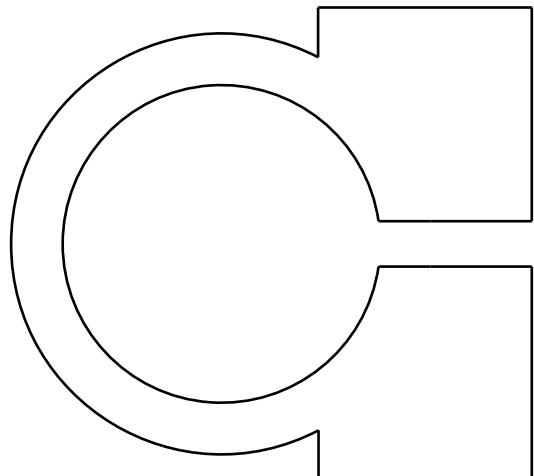
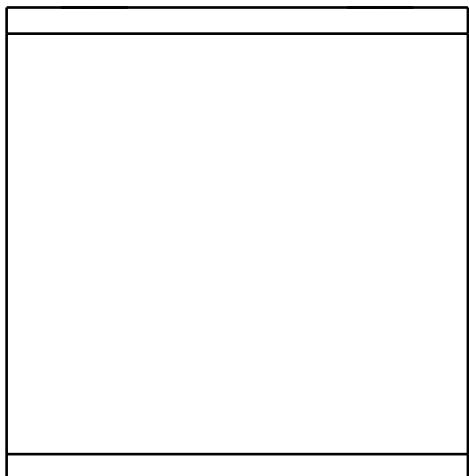
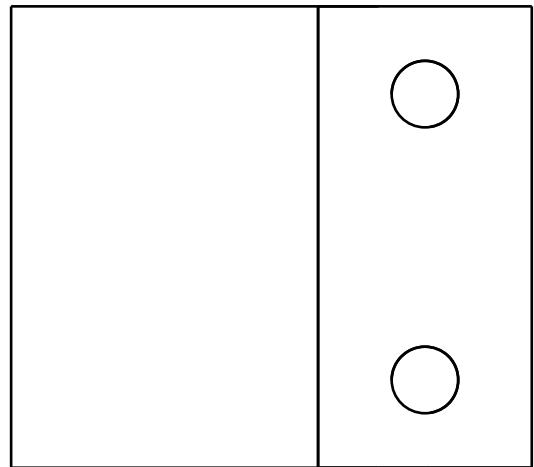
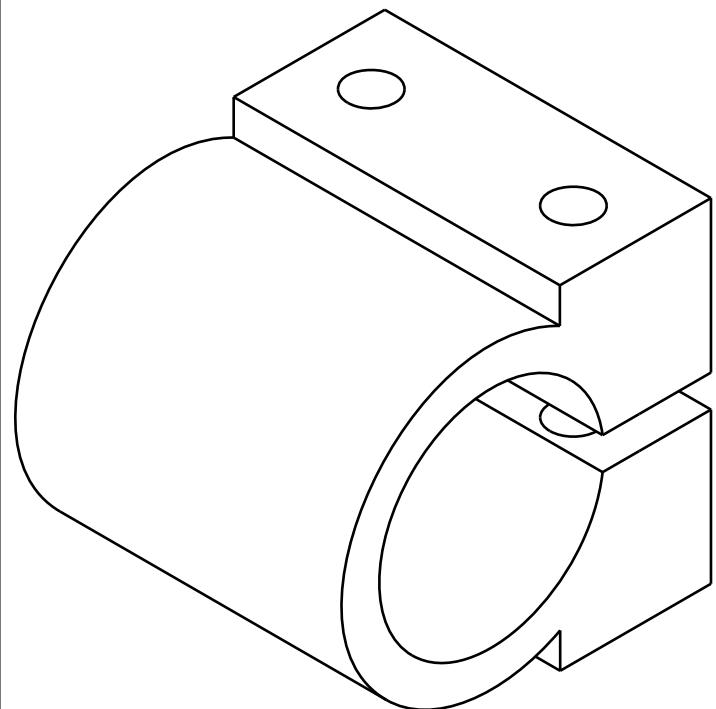
Date:

01/06/2016

Revision:

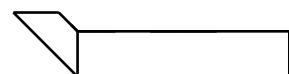
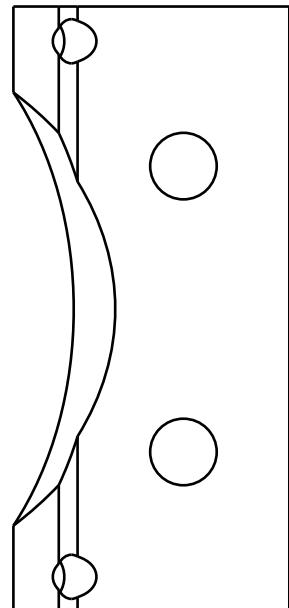
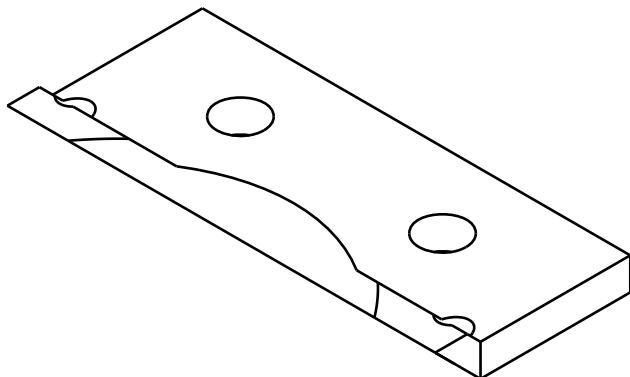
REV A





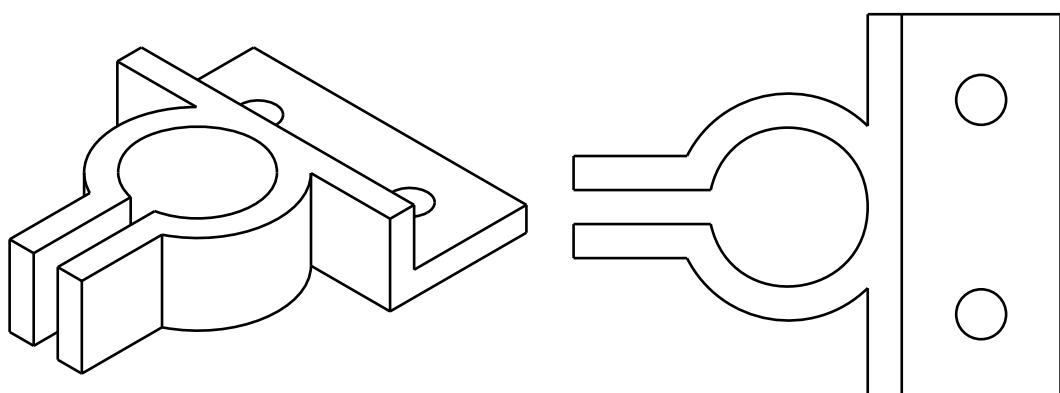
Created by: Antonio Jurado Caballero	Title: Carriage Clamp LM12UU	
Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4	Sheet: X / Y
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	Part number: v 1.0.	
	Drawing number: 12	
	Date: 01/06/2016	Revision: REV A





Created by: Antonio Jurado Caballero	Title: Carriage Fanmount			
Supplementary information: FINAL DEGREE PROJECT: Hardware modification of a 3D printer to make prints by means of using two extruders in parallel.	Size: A4	Sheet: X / Y	Scale: 2:1	
	Part number: v 1.0.			
	Drawing number: 13			
	Date: 01/06/2016	Revision: REV A		





Created by: Antonio Jurado Caballero	Title: Carriage Cablemount	
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	Scale: 1:1,5	
	Part number: v 1.0.	
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2.2 Unprintable parts

In this section all the parts that can not be printed with a 3D printer and are required for the modification are described. The parts are:

- **Pulley 16 for nema 17**



Figure 2.18: Pulley 16 for nema 17 (Source: lulzbot^[8])

- **Belt 9mm**



Figure 2.19: Belt 9mm (Source: RepRap Germany^[1])

- **M6x22 cylinder head screw**



Figure 2.20: M6x22 cylinder head screw (Source: arz-tuning^[9])

- **M6 T slot nut**



Figure 2.21: M6 T slot nut (Source: Amazon^[10])

- **Spacer profile, 55 mm**

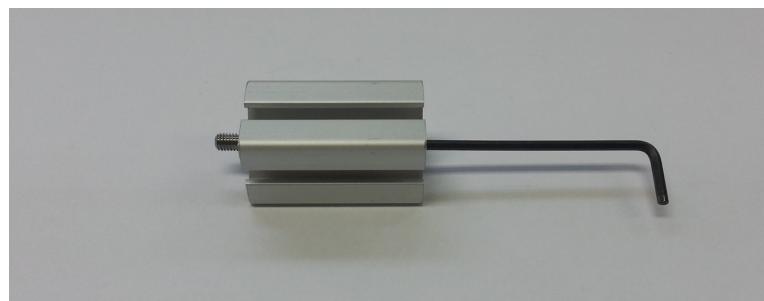


Figure 2.22: Spacer profile, 55 mm (Source: RepRap Germany^[1])

- **X-axis hollow shaft, long, 530 mm**
- **X-axis hollow shaft, short, 500 mm**



Figure 2.23: X-axis hollow shaft, 530 mm and 500 mm (Source: RepRap Germany^[1])

- **Ball bearing LM12UU**



Figure 2.24: Ball bearing LM12UU (Source: Amazon^[10])

- M4x30 cylinder head screw



Figure 2.25: M4x30 cylinder head screw (Source: Amazon^[10])

- M4x120 cylinder head screw
- M4 washer



Figure 2.26: M4 washer (Source: Amazon^[10])

- M4 self-locking nut



Figure 2.27: M4 nut (Source: Amazon^[10])

- M3x40 cylinder head screw



Figure 2.28: M3x40 cylinder head screw (Source: Amazon^[10])

- M3x20 cylinder head screw
- M3 washer
- M3 self-locking nut
- Bearing 608-ZZ
- Cylinder fitting screw
- M6 washer
- M8 washer
- M6 self-locking nut

2.3 Electronic

In this section all the electronic parts that are necessary for the modification are presented. The parts are:

- **End-Stop**



Figure 2.29: End-Stop (Source: RepRap Germany^[1])

- **Nema 17**

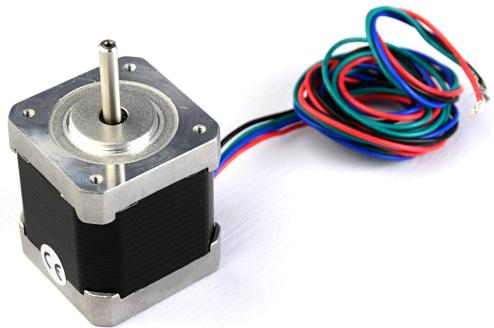


Figure 2.30: Nema 17 (Source: ARS Electronica^[11])

- **Complete extruder with fan**

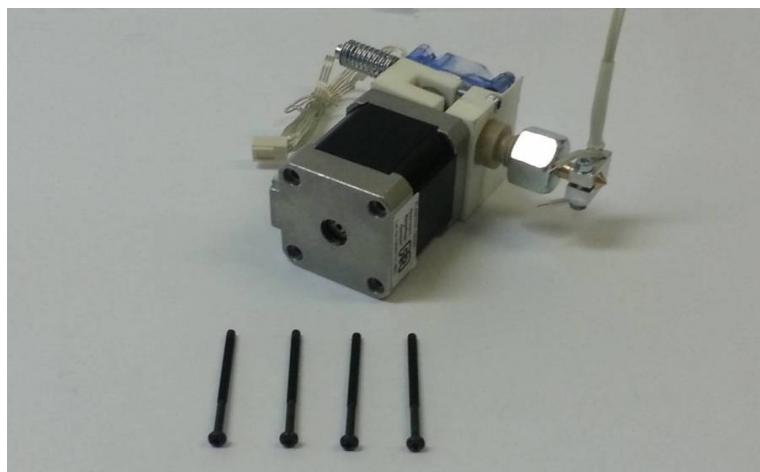


Figure 2.31: Complete extruder with fan (Source: RepRap Germany^[1])

- **Cable loom extruder**



Figure 2.32: Cable loom extruder (Source: RepRap Germany^[1])

- **Cable loom X-/Y-axis**



Figure 2.33: Cable loom X-Y-axis (Source: RepRap Germany^[1])

Part III

Set up

Chapter 3

Set up

In this chapter it is explain how to mount the parallel 3D printer, using all the components listed above. First, a list of materials needed are presented. Secondly, the assembly process of the new components to the structure is described. Finally, it is explained the assembly of the electronic system and some points to be considered after mounting parallel 3D printer.

3.1 List of all parts

- 2 und. Modified X-glider
- 2 und. Modified X-glider clamp LM12UU
- 4 und. Modified X-glider clamp belt
- 4 und. Modified POM NEMA 17 Mount
- 1 und. Activator X-Axis End-stop
- 1 und. Carriage Cablemount
- 2 und. Carriage Clamp LM12UU
- 1 und. Carriage Fanmount
- 1 und. Carriage Mount
- 1 und. Carriage Clamp Belt
- 1 und. Extruder filament support, Front piece ver.3 (optional)
- 1 und. Extruder filament support, Back piece ver.2 (optional)
- 3 und. Pulley 16 - M8 (printed or metal)
- 2 und. Filament support Left and Right (optional)
- 1 und. Cabling Support
- 3 und. Pulley 16 for nema 17

- 400cm Belt 9mm
- 20 und. M6x22 cylinder head screw
- 21 und. M6 T slot nut
- 1 und. Spacer profile, 55 mm
- 1 und. X-axis hollow shaft, long, 530 mm
- 1 und. X-axis hollow shaft, short, 500 mm
- 6 und. Ball bearing LM12UU
- 4 und. M4x30 cylinder head screw
- 2 und. M4x120 cylinder head screw
- 12 und. M4 washer
- 6 und. M4 self-locking nut
- 28 und. M3x40 cylinder head screw
- 1 und. M3x20 cylinder head screw
- 52 und. M3 washer
- 24 und. M3 self-locking nut
- 3 und. Bearing 608-ZZ.
- 3 und. M6 self-locking nut
- 3 und. M6 washer
- 12 und. M8 washer
- 1 und. End-Stop
- 3 und. Nema 17
- 1 und. Complete extruder with fan
- 1 und. Cable loom extruder
- 1 und. Cable loom X-/Y-axis

3.2 Structure set up

Here it is explained step by step how to modify in the structure of the X400 CE 3D printer. It starts with both axes, continues with the extruder support and finishes with the explanation of the optional add-ons.

3.2.1 X-Axis

- Install the pulley, end-stop and the Nema17 on the Modified X-glider .

The pulley is assembled, being possible to select a printer pulley (Reference to Figure 2.16) or a metallic one.¹ It must be as follows:



Figure 3.1: Details cylinder fitting screw (Source: RepRap Germany^[1])

In one of the X-glider, is screwed the Nema 17 with the pulley, 16 teeth 5mm hole (plus grub screw). The *X-glider* with the Nema 17 shall be located on the right side. The Nema connector must be placed on the left side. Once this is done, the endstop is set. It is shown in the following image:

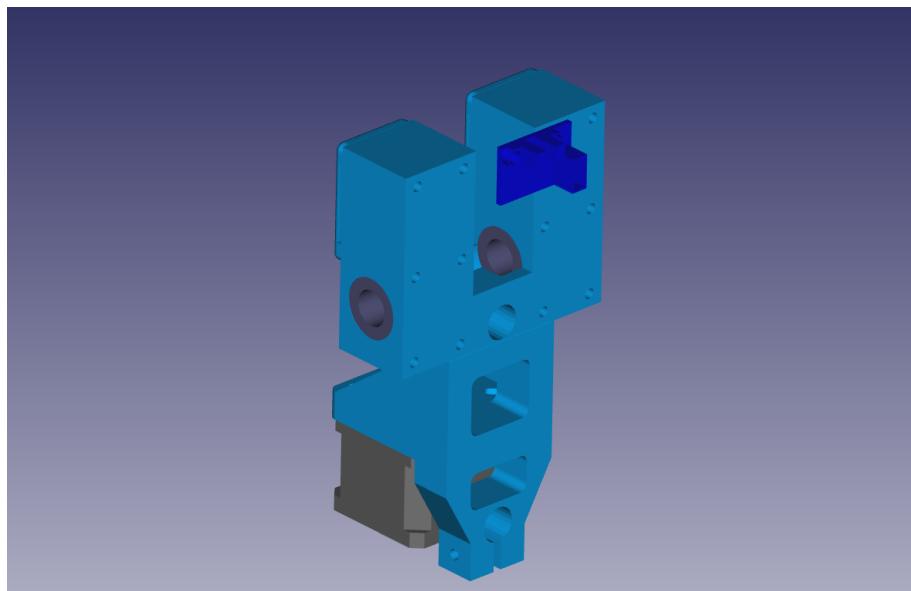


Figure 3.2: Front X-glider mount with nema 17

¹"If there are doubts you can consult the manual X 400 ce [1]."

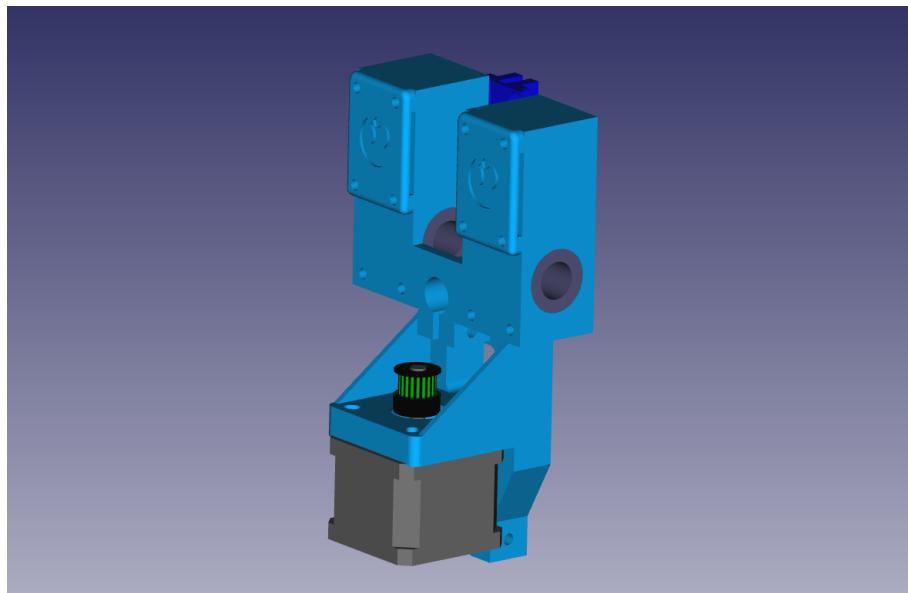


Figure 3.3: Back X-glider mount with nema 17

In the other *X-glider*, it is introduced a bearing 608-ZZ and then the pulley. Once this is done, the endstop is set on the right side. It is necessary a small hole for inserting the screw, M3x20. This can be seen in the following image:

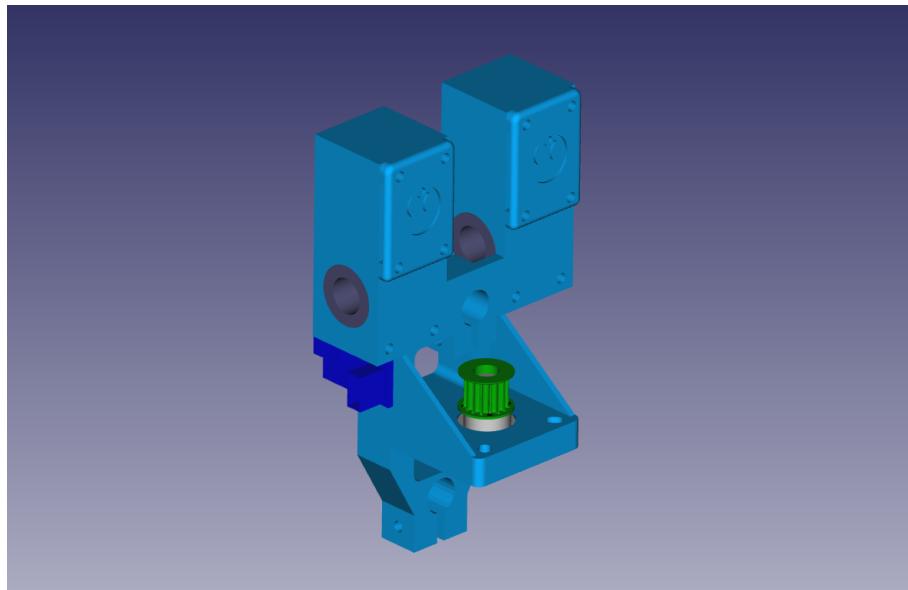


Figure 3.4: X-glider mount with pulley

- Assembly X-glider

Insert the remaining screws in the other holes and the ball bearing LM12UU in the big hole. Do not forget the ones for the belt clamp. It is recommended not to tighten the screws yet being that the bearings still need to be inserted.

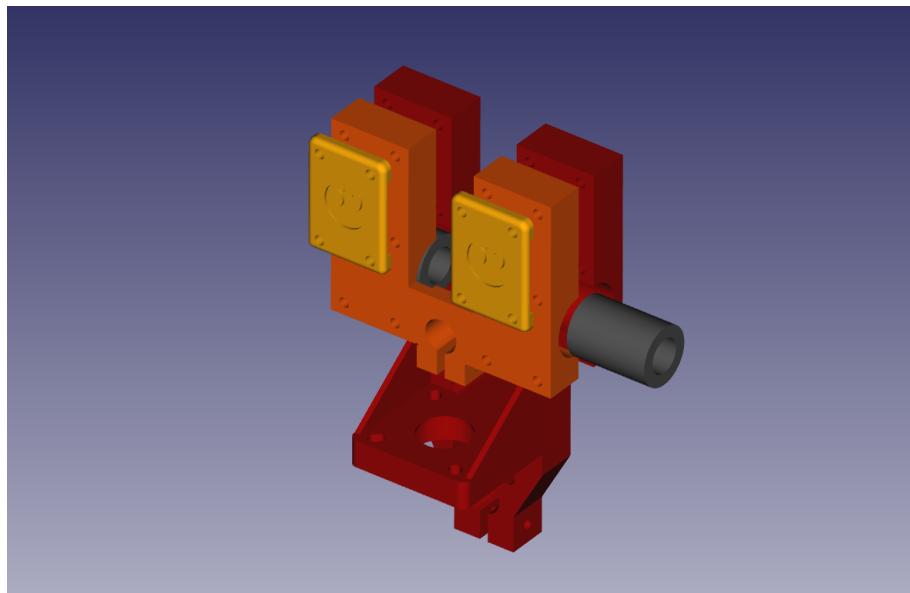


Figure 3.5: Assembly X-glider

- Extruder carriage

Insert one *carriage clamp LM12UU* (Reference to Figure 2.8) with the ball bearing LM12UU for each X-axis hollow shaft. Afterwards, the long shaft is inserted at the top of the *X-glider*, as shown in the following image:

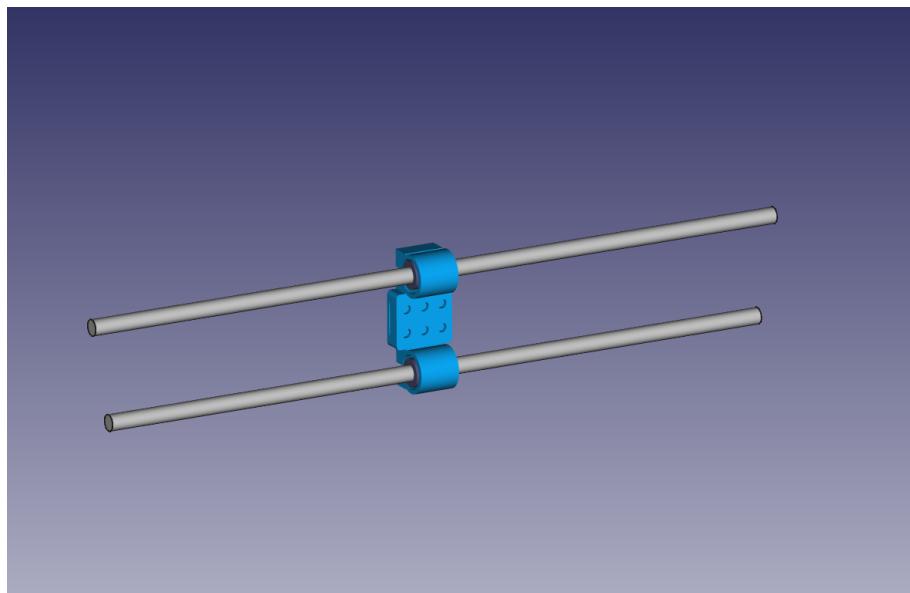


Figure 3.6: Position of the shaft

Now, the missing parts of the carriage are mounted. The screws M4x120 are used, these will be introduced at the lower part. The *carriage clamp belt* (Reference to Figure 2.11) will be mounted later next to the extruder. It is important to bear in mind the orientation of the part where the extruder will be connected.

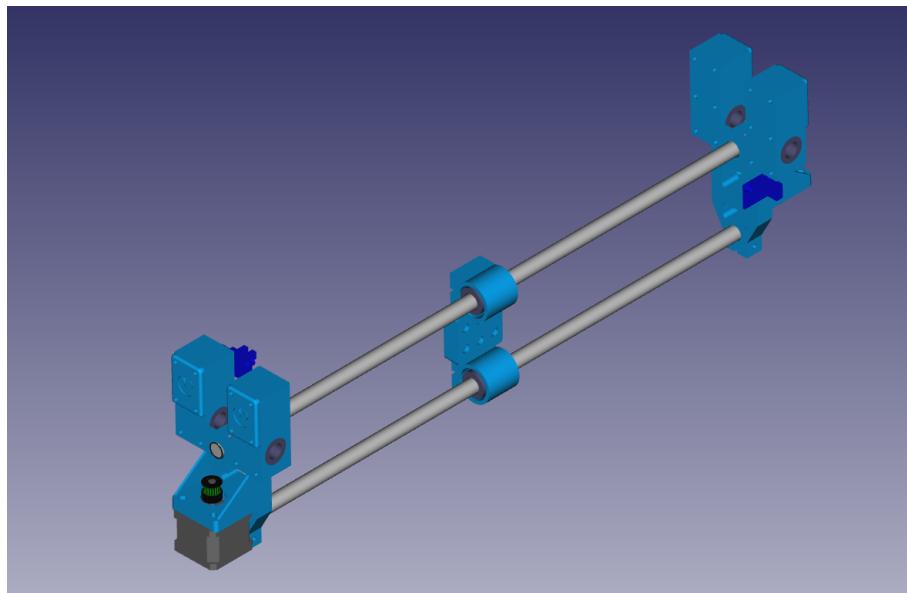


Figure 3.7: X-Axis complete without drive belt

- Insert this new X-Axis

Finally it is inserted this new X-Axis near to the other X-Axis, using the same Y-Axis shaft. It is necessary to put the part with a Nema 17 on the right.

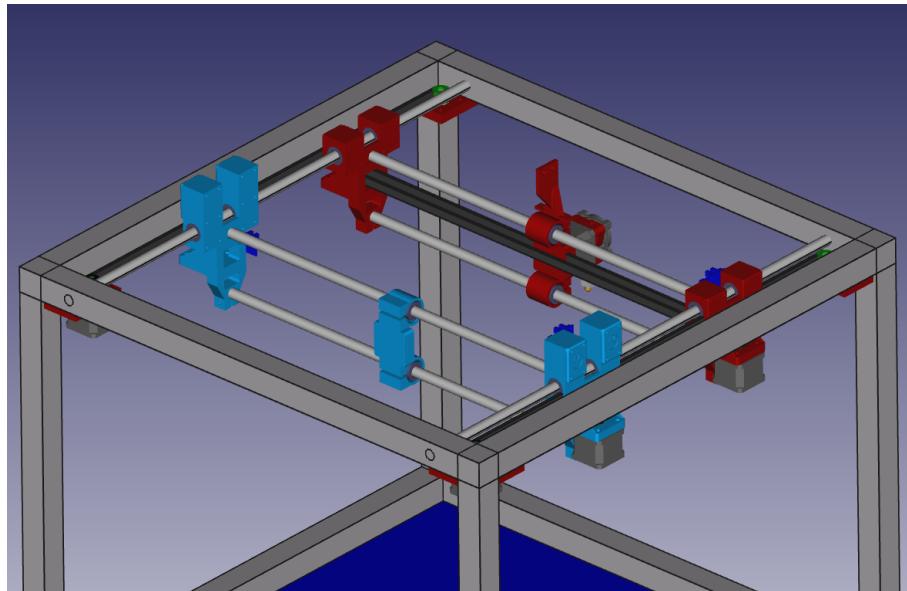


Figure 3.8: New mod X-Axis mount

3.2.2 Y-Axis

- Install the pulley and the Nema17 on the parts.

As in the X-Axis, first the pulleys and Nema17 in the *POM NEMA 17 Mount Modified* (Reference to Figure 2.4) are included. Two parts will have a pulley and the other two, a Nema 17. Both of them must be mounted face off. This can be seen in the following image:

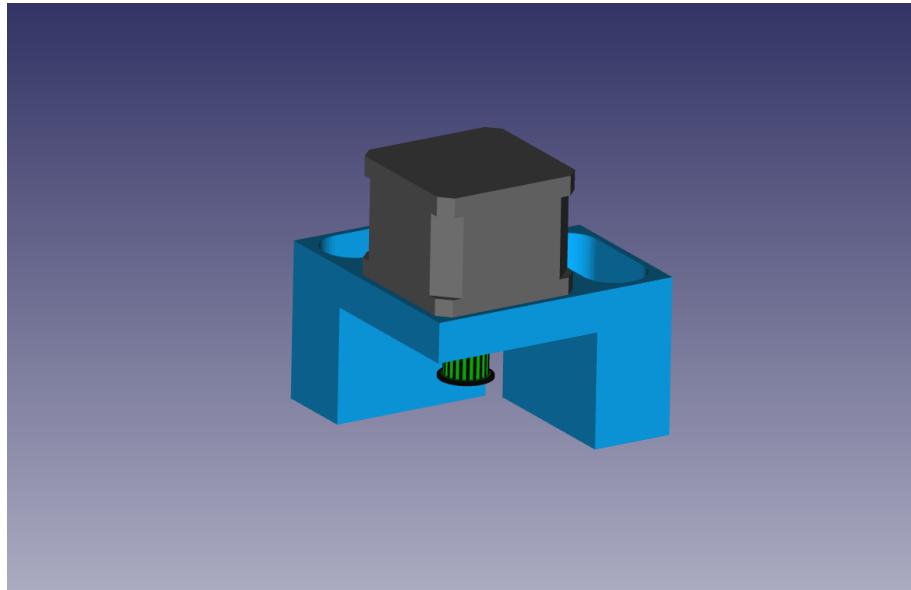


Figure 3.9: Modified POM NEMA 17 Mount with Nema

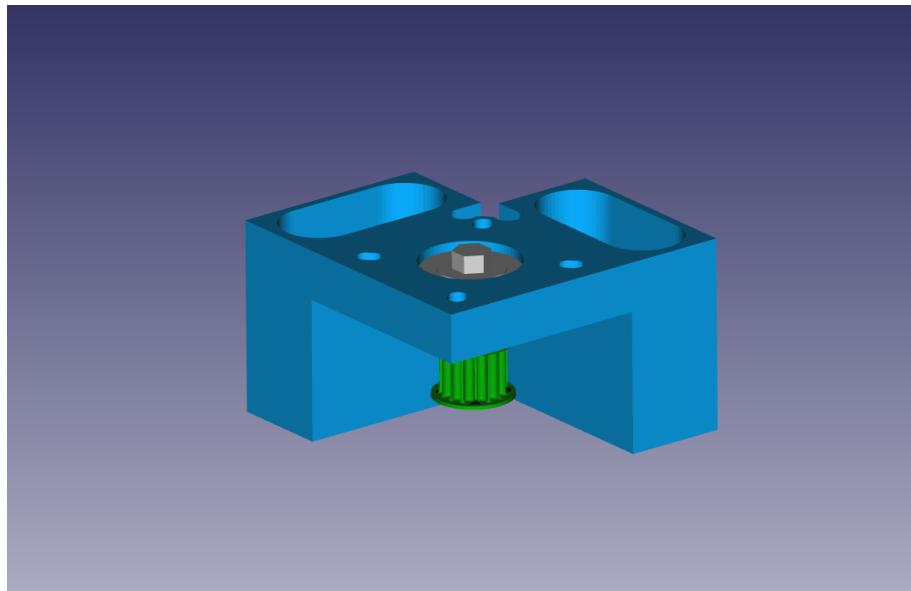


Figure 3.10: Modified POM NEMA 17 Mount with Pulley

- Put parts of the Y-Axis on the chassis.

Each *Modified POM NEMA 17 Mount* is fastened using four bolts. The *M6 T-Nutenstein* has a rim where the ball bearing sits on. These rings are facing down on the bottom of the frame.



Figure 3.11: Details Bearing holders T-nuts (Source: RepRap Germany^[1])

The parts are set on the structure as shown in the following image. The Nema 17 is placed at the rear and the pulleys, at the front.

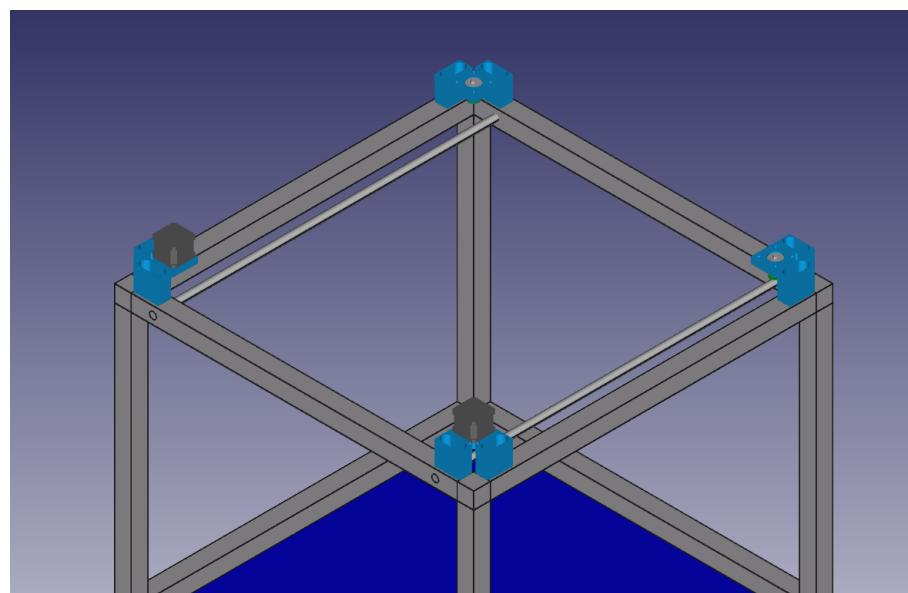


Figure 3.12: Y-Axis mod mount

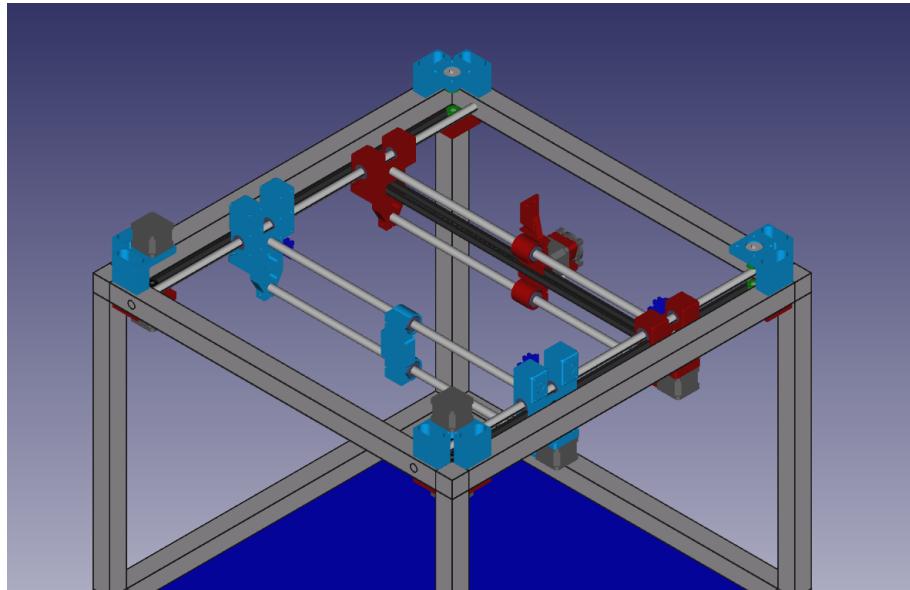


Figure 3.13: Y-Axis mod mount

- Connect the belts

It is connected the Y-Axis to X-Axis by two drive belts. One belt is placed in the right part and one, in the left part of the 3D printer. This must be stretch.

At this time the screws of the X-Glider must be tightened.

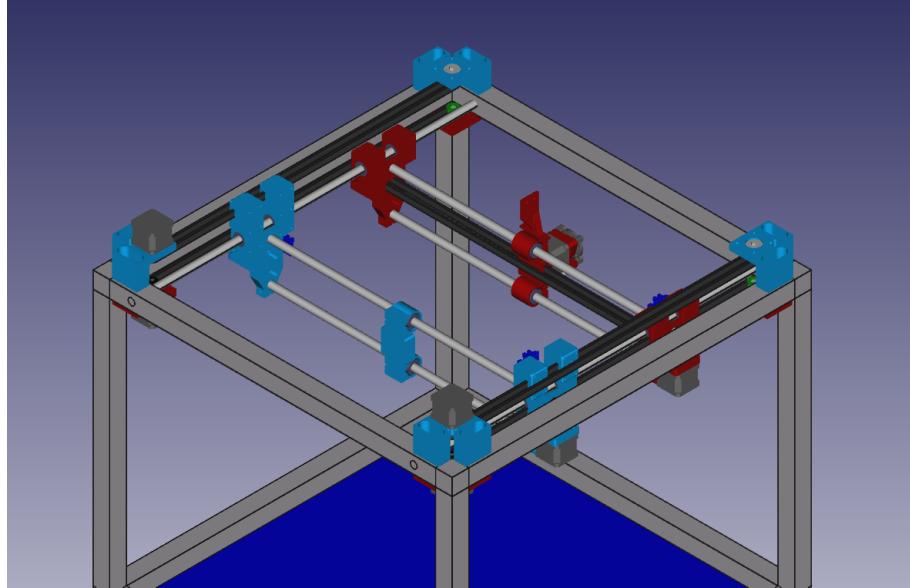


Figure 3.14: Y-Axis mod mount with belts

3.2.3 Extruder

- Mounting the extruder

Mount the extruder on the *Extruder carriage*. The extruder should be put in the opposite direction to the original extruder.

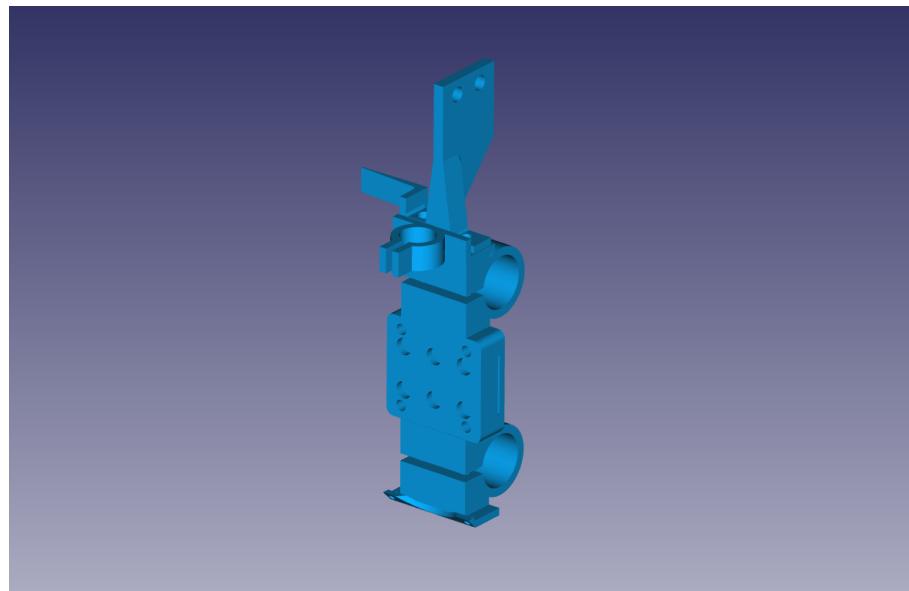


Figure 3.15: Extruder carriage

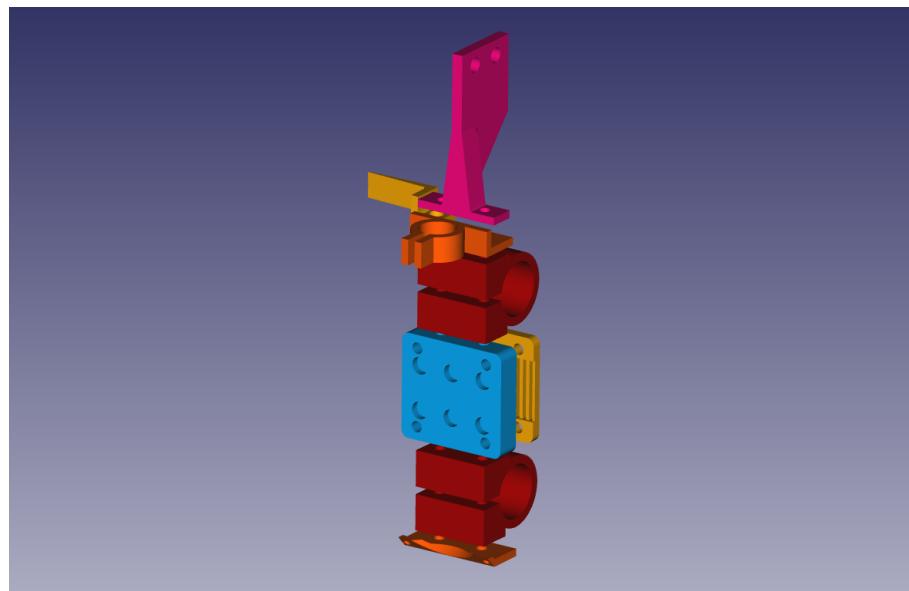


Figure 3.16: Extruder carriage

- Mounting the belt extruder carriage to X-Axis

The two *X-glides* are connected to the *Extruder carriage* by a drive belt. It must be used the *Carriage Clamp Belt* to hold the drive belt.

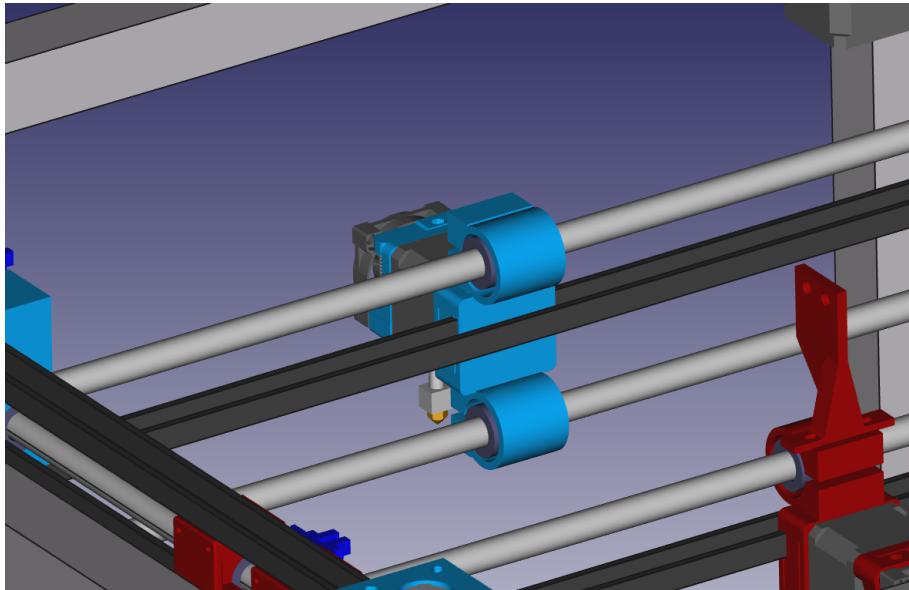


Figure 3.17: Extruder with belt

- Complete the extruder carriage

Finally, the *Activator X-Axis End-stop* (Reference to Figure 2.7) and the *Carriage Carriage Mount* (Reference to Figure 2.6) are mounted. With this parts, the structure of the modified 3D printer is completed.

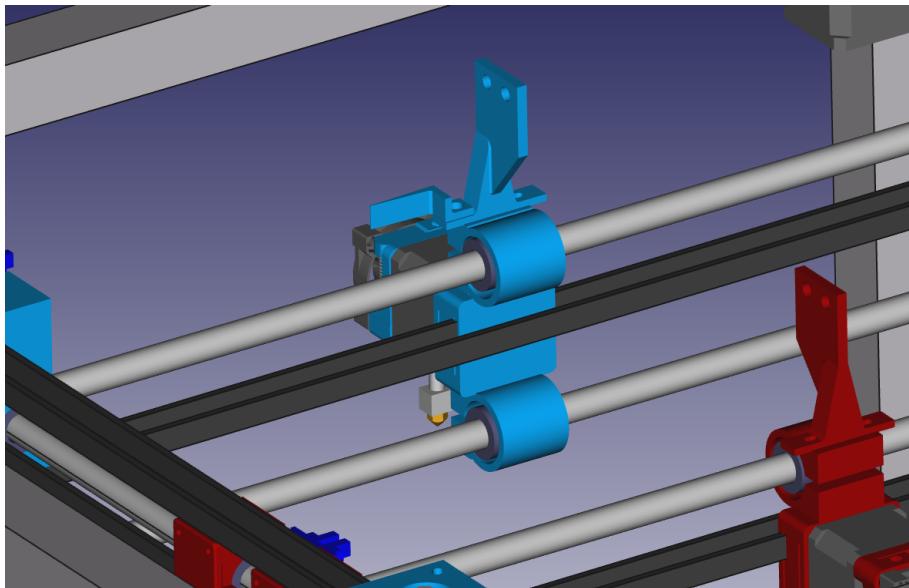


Figure 3.18: Complete extruder

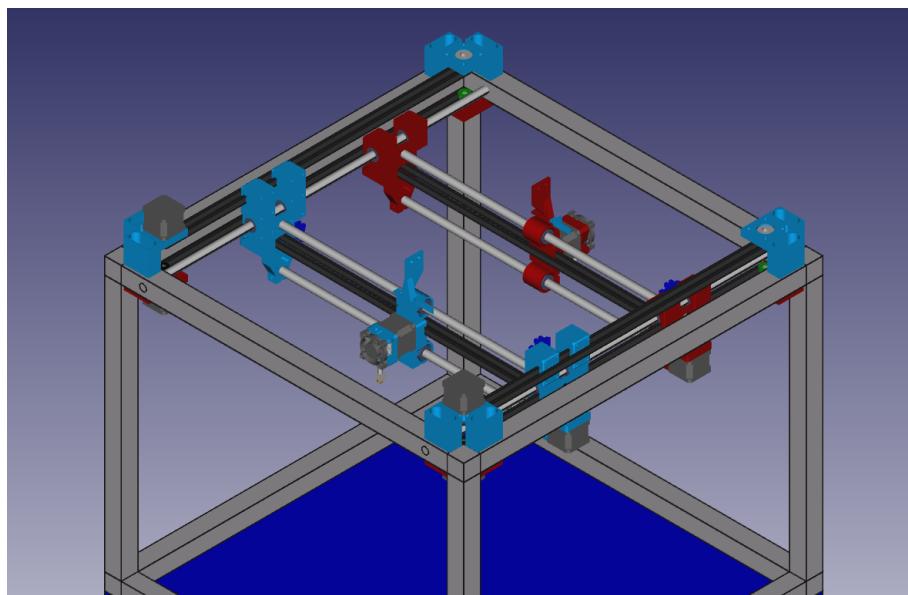


Figure 3.19: Complete X400 CE mod without add-ons

3.2.4 Add-ons

- Filament support

It should be mounted a support on the front to hold the filament of the first extruder as well as another at the back, which will hold the filament of the new extruder. The filament support consists of two parts (Reference to Figure 2.14 and 2.15)

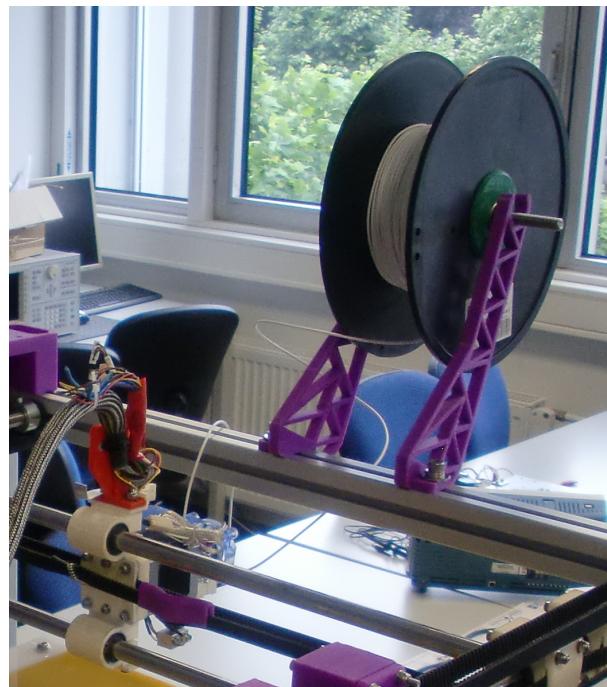


Figure 3.20: Filament support

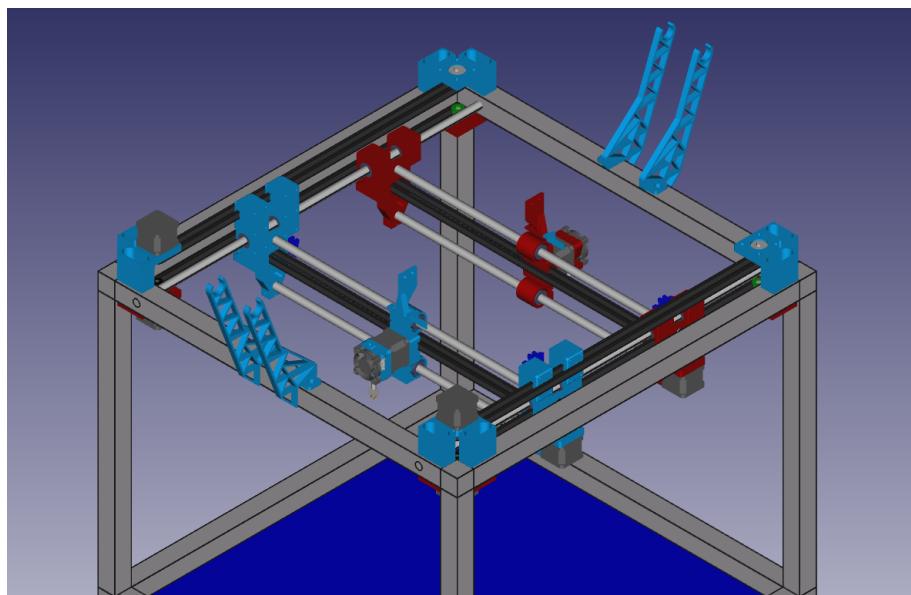


Figure 3.21: Complete X400 CE mod with filament support

- Improved extruder

This modification improves the path of the filament through the extruder. In addition, it improves the form of penetrating and taking out the extruder filament.

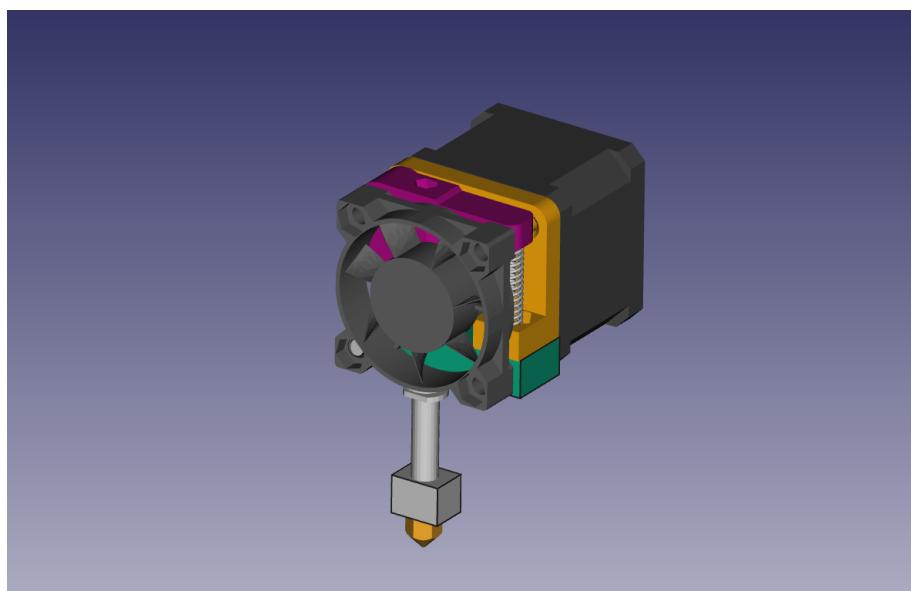


Figure 3.22: Extruder modified

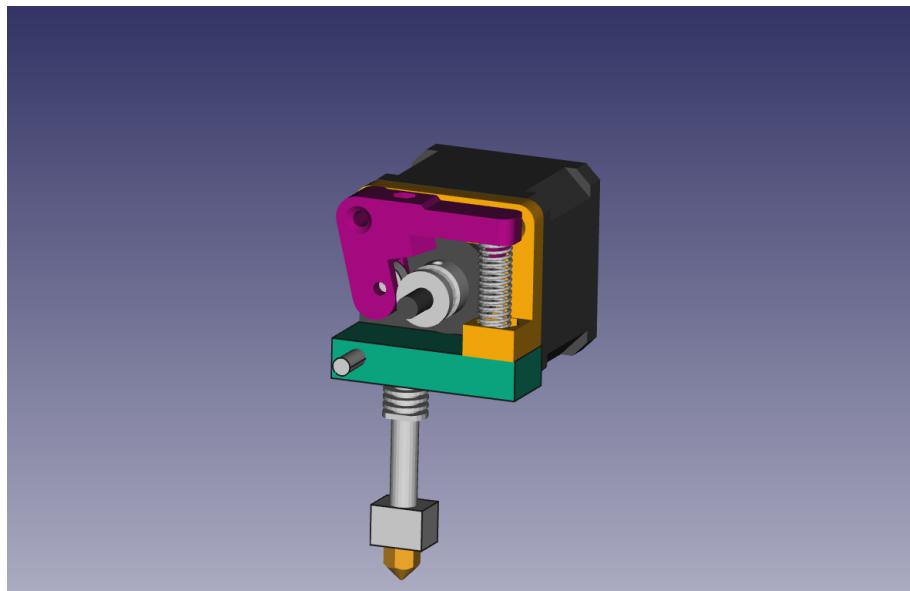


Figure 3.23: Extruder modified

- **Tensioner for the drive belt**

It is a good habit to leave the drive belts very tense. It is recommended to look for a good design in *thingiverse* [2] or using the same in this document, which is attached.

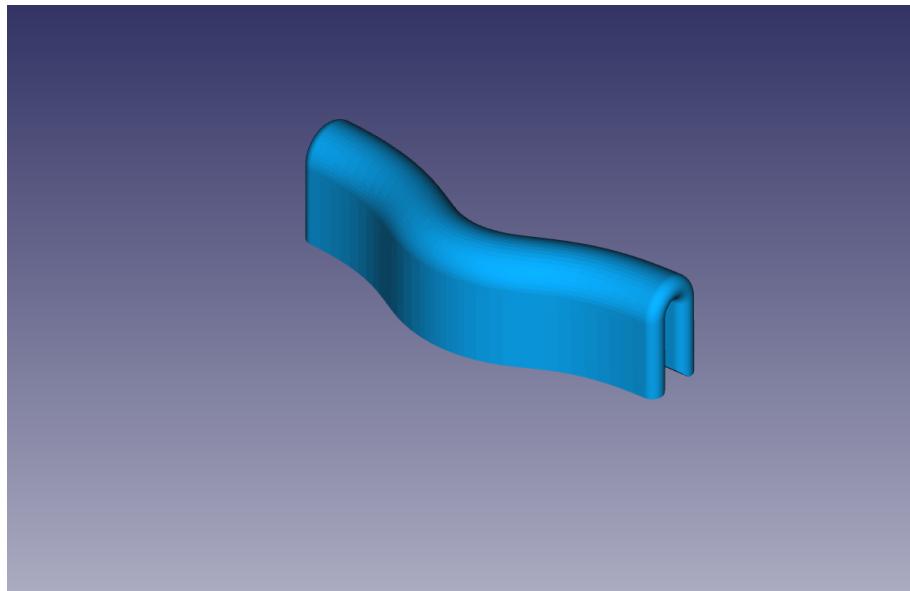


Figure 3.24: Belt tensioner

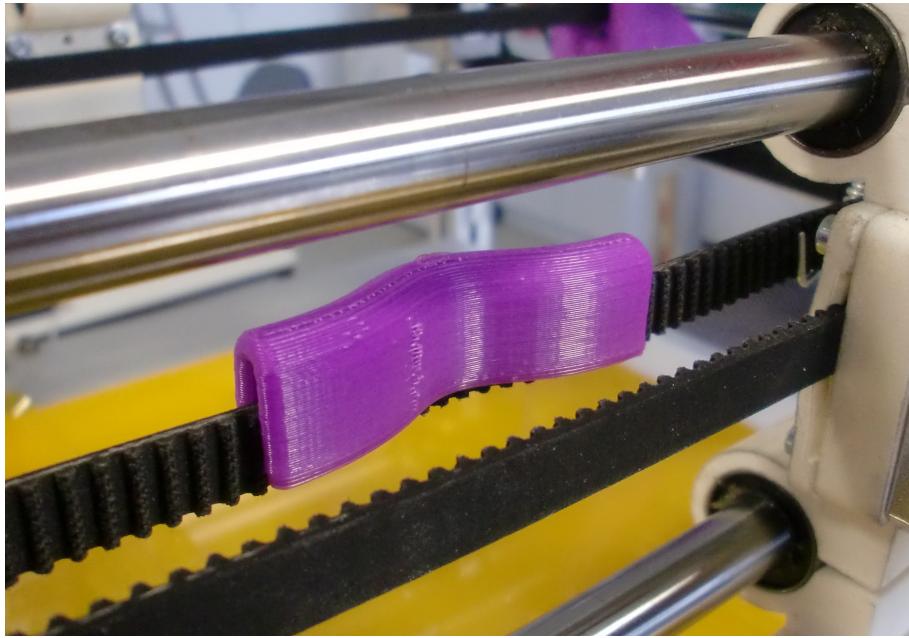


Figure 3.25: Belt tensioner mount

3.3 Set up and configuration of the electronic

In this section it is indicated how to connect the electrical wiring, first extruder and finally the rest of the elements.

- Extruder connection

It will hold the *Cable loom extruder* (Reference to Figure 2.32) to the *Cabling Support* by means of mounting flanges. This *Cable loom extruder* shall be attached to the structure by the profile Spacer, 55 mm. It is mounted in a side of the junction box. This can be seen in the following image:

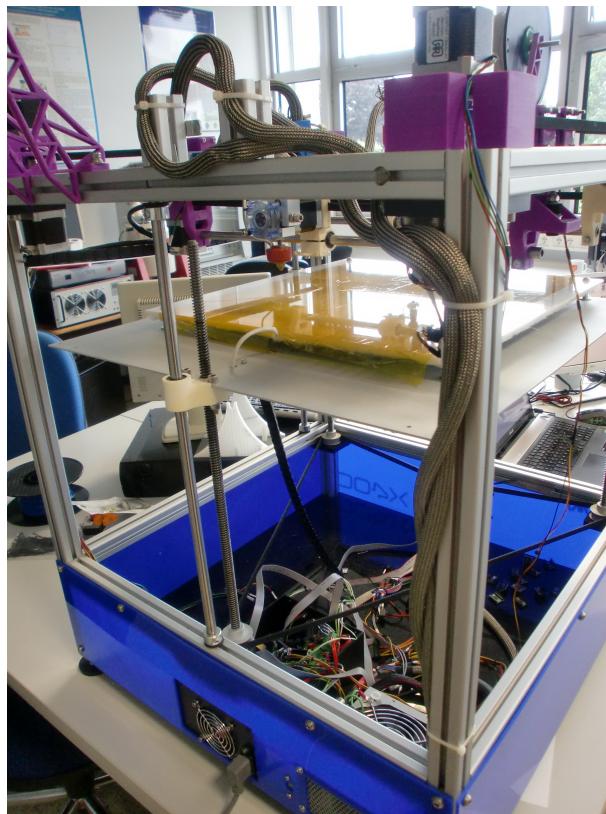


Figure 3.26: Cable loom extruder mount

Once this is done, the Nema 17, fan, hot-end heater and thermal sensor are connected.²

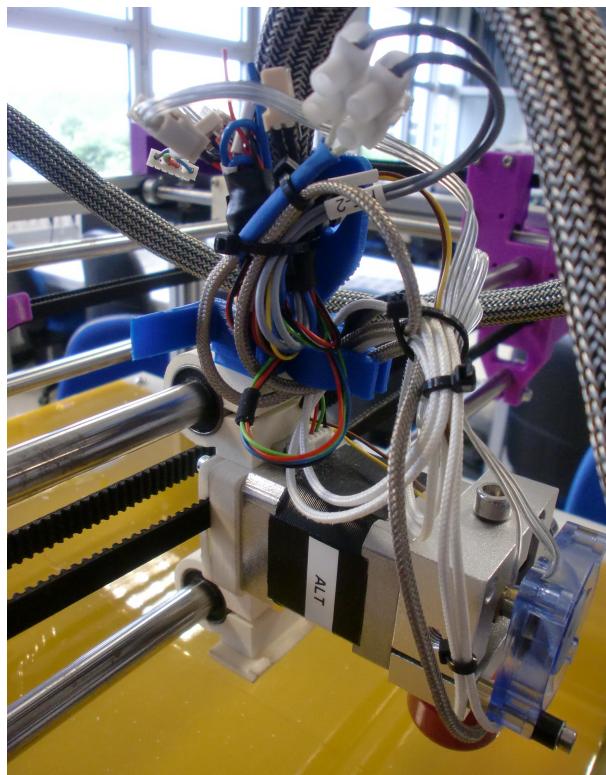


Figure 3.27: Cable loom extruder mount

²"If there are doubts you can consult the manual X 400 CE [1]."

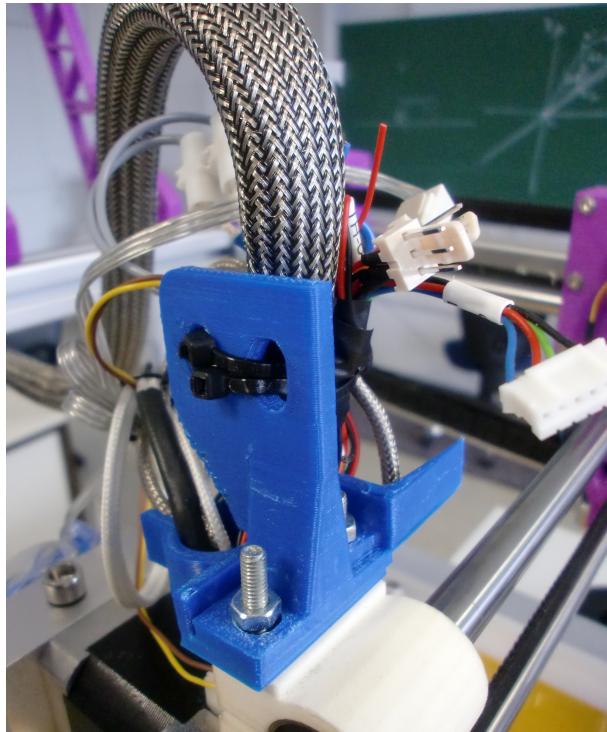


Figure 3.28: Cable loom extruder mount

- Step-motors and End-stop connection

Install the *Cable loom X-/Y-axis* (Reference to Figure 2.33). The labels shown in the cable must be followed. It should be considered that the end-stop to the left of the X-Axis, now is the Endstop of the Y-Axis. Then it is mounted in a side of the junction box.

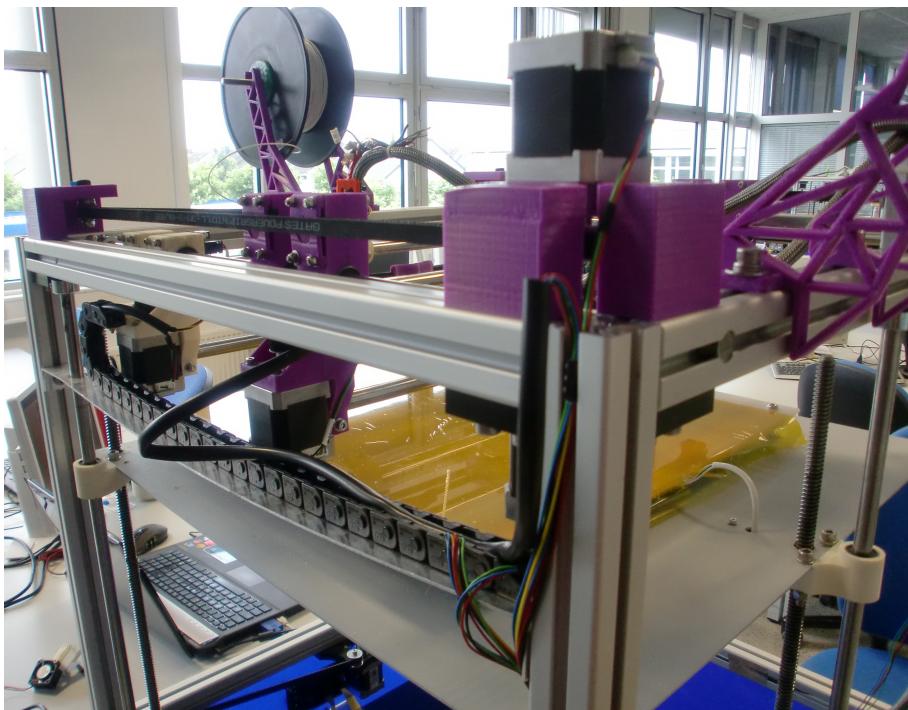


Figure 3.29: Cable loom X-/Y-axis mount

Chapter 4

Test and observation

In this section, a series of guidelines to test the new parts is indicated and also some points to consider are indicated.

- For testing, it can be used the same electronics, RAMPS 1.4.1 and Arduino Mega, which includes the X400 CE 3D printer. Only it must be changed the end-stop of X-Axis, step-motors of X-Axis, Y-Axis and the extruder.
- The new X-Axis is oriented in a way contrary to the original X-Axis, making the Y-axis calibration inversely. So this end-stop will have two functions, calibration the Y-Axis and avoiding collisions. To reverse the step-motors, it is possible to change it by software or by connecting the motors to the RAMPS in reverse order.

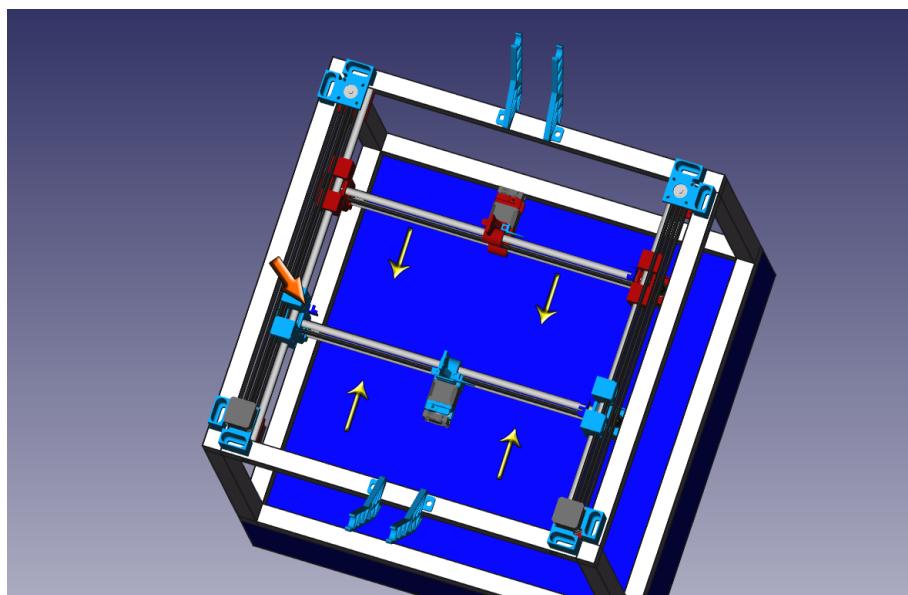


Figure 4.1: Direction to calibration X-axis

- By software, it is indicated that the print area is half, preventing that the extruder leaks out of the printing area. As a recommendation, it is indicated 190x400x330 (w,d,h).
- Now, the original Y-axis end-stop is removed because it is not used.

- Inasmuch the original manual does not indicate how to calibrate the 3D printer, here are some interesting links [3] [4] [5].
- If there are problems with calibration after consulting the links above, it is recommended those links that focus more on each particular problem [6] [7].

Bibliography

- [1] GERMAN REPRAP X400CE 3D Printer Manual [online].[Date consulted: 2 August 2016] Available in: <http://wiki.germanreprap.com>
- [2] THINGIVERSE Mk8 upgrade without cutting for REP 2 [online].[Date consulted: 15 July 2016] Available in: <http://www.thingiverse.com/thing:35810>
- [3] REPRAP Calibration/es [online].[Date consulted: 2 July 2016] Available in: <http://reprap.org/wiki/Calibration/es>
- [4] CAPALTRES Calibration Prusa i3 [online].[Date consulted: 2 July 2016] Available in: <http://www.capaltresd.com/wordpress/wp-content/uploads/2015/04/Calibrado-Prusa-i3.pdf>
- [5] INGENIO-TRIANA Calibration Prusa i3 [online].[Date consulted: 3 July 2016] Available in: <http://ingenio-triana.blogspot.de/2015/04/pasos-para-calibrar-una-impresora.html>
- [6] LEON-3D 3D printer Troubleshooting Guide [online].[Date consulted: 14 July 2016] Available in: <http://www.leon-3d.es/guia-de-resolucion-de-problemas/>
- [7] IKASLAB 3D printer Troubleshooting Guide [online].[Date consulted: 14 July 2016] Available in: <http://wiki.ikaslab.org/>
- [8] LULZBOT 3D printer Store [online].[Date consulted: 9 August 2016] Available in: <https://www.lulzbot.com>
- [9] ARZ-TUNING M6x22 screw photo [online].[Date consulted: 9 August 2016] Available in: <http://www.arz-tuning.de>
- [10] AMAZON Amazon shop webpage [online].[Date consulted: 9 August 2016] Available in: <https://www.amazon.de>
- [11] AMAZON Blog about electronic [online].[Date consulted: 9 August 2016] Available in: <http://blog.ars-electronica.com.ar>