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3D Printing of an Electrodynamics Loudspeaker Driver

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INTRODUCTION

Context 3D printing with Fused Deposition Modelling (FDM) [1] is a mature and affordable manufacturing process for rapid prototyping.

Idea Explore the possibilities to 3D print an electrodynamic loudspeaker using an FDM thermoplastic printer and minimum extra parts.

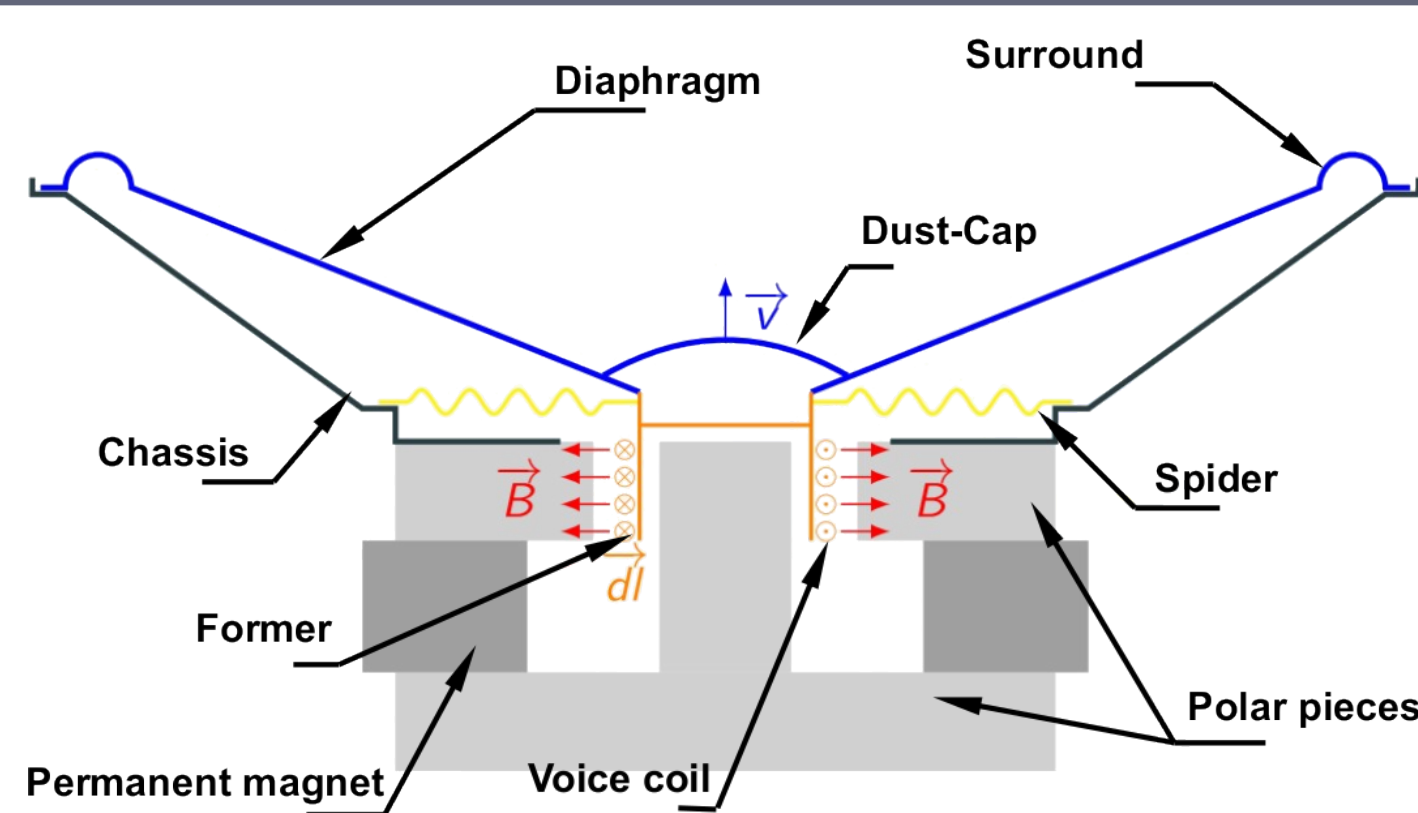
Goal Propose a possibility to build "at home" a transducer with acceptable acoustic performance at a minimal cost.

Interests Do It Yourself (DIY), Educational, Economic

Challenges Typical designs of electrodynamic loudspeakers are reconsidered to be built with FDM.

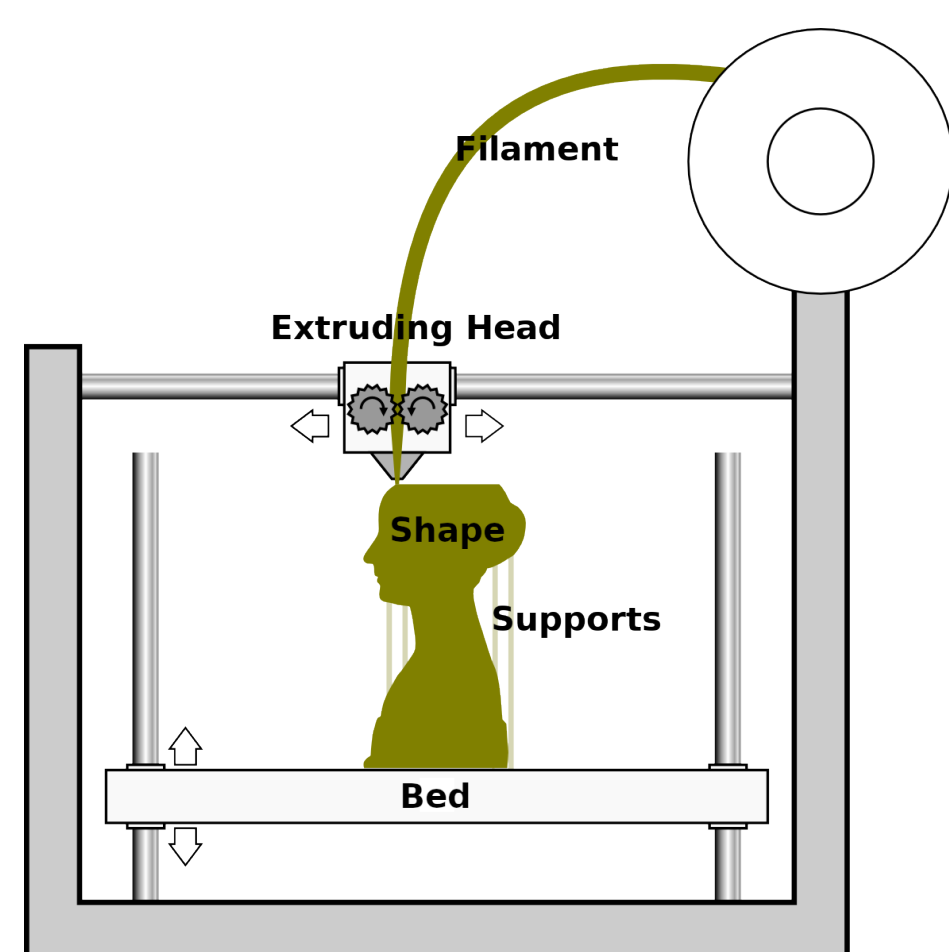
Background Some attempts for 3D printed loudspeaker [2][3][4].

ELECTRODYNAMIC LOUDSPEAKER [5]



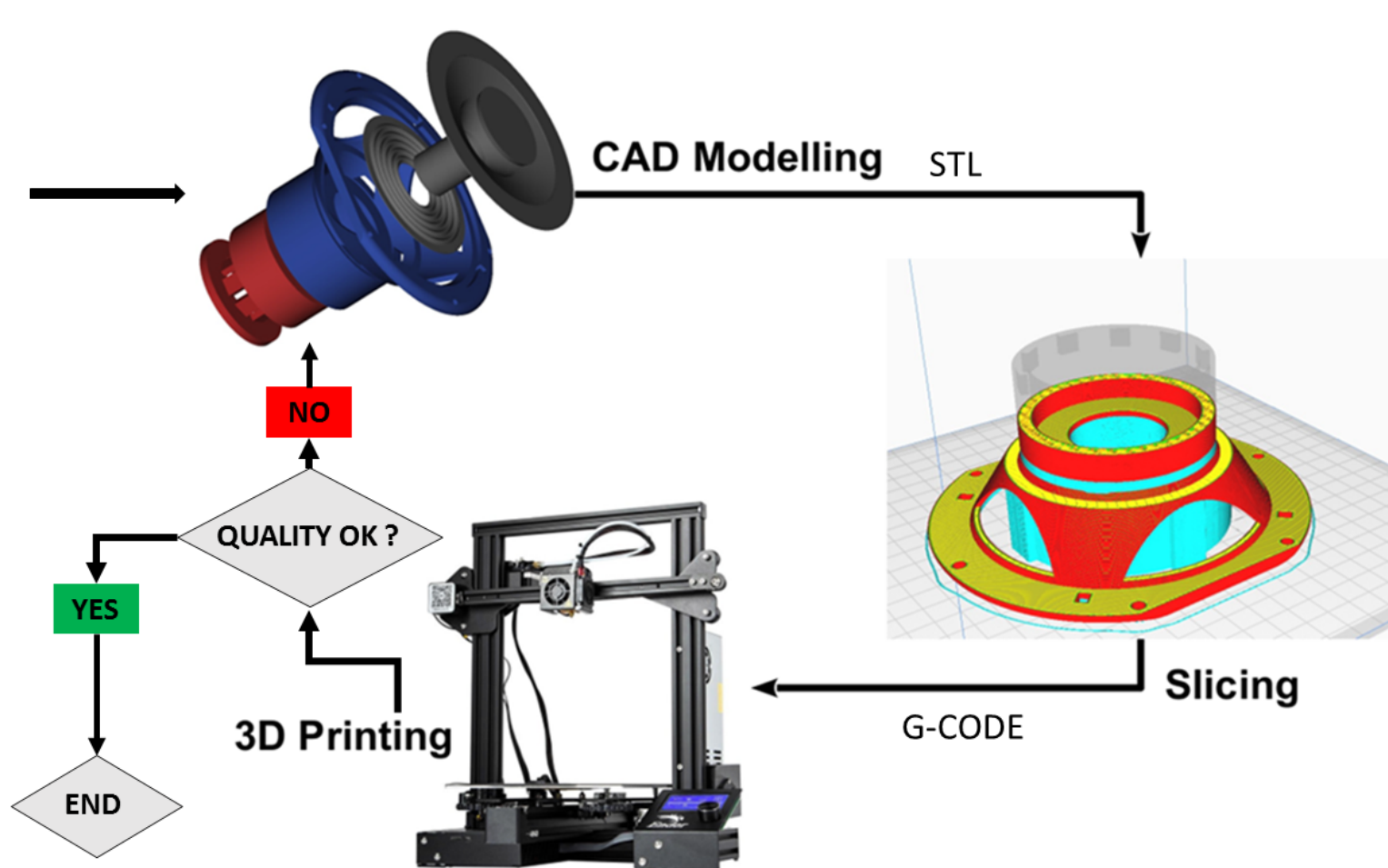
- A permanent radial magnetic field \vec{B} is applied on a cylindrical voice coil.
- When a current i flows through the coil of length L , an axial Laplace force is generated: $F = B * L * i$.
- Mechanical motion is induced to the diaphragm: \vec{v}
- Pressure p is radiated, ideally proportional to i .

FUSED DEPOSITION MODELLING [1]



- A thermoplastic filament is fused in an extruding head.
- It is deposited layer by layer to build the desired shape.
- At each layer, the bed (or the extruding head) is translated vertically from a layer height.
- Strong overhangs require removable supports, printed together with the part.
- Supports can be hard to remove and compromise the part final appearance.
- The print quality depends on many factors: material, printing speed, layer height, etc.

WORKFLOW



- Each part is drawn using a Computer Aided Design (CAD) software (in this work, FreeCAD 0.18).
 - ▷ During the drawing, overhangs are limited to reduce the use of supports.
 - ▷ The resulting solid model is exported using STereoLitography (STL) format.
- The STL file is prepared using a slicing software (in this work, Cura 4.0)
 - ▷ The solid shell and inner volume are considered separately.
 - ▷ Many parameters are adjusted : nozzle size, layer heights, wall thickness, printing temperature, etc.
 - ▷ The result is exported as G-CODE instruction file.
- The 3D printer (in this work, Creality Ender-3) runs the instructions and print the part.
- If the physical part meets the requirements, the process ends. Otherwise, CAD and slicing processes are adjusted.

PARTS FEATURES

Each part requires specific mechanical properties. It is associated with specific printing parameters and material:

Chassis printed in Polyactic Acid (PLA) or Acrylonitrile Butadiene Styrene (ABS) with thick shell and infill to improve stiffness and limit vibrations.

Surround printed flat at low speed in Thermoplastic polyurethane (TPU) flexible filament. Brim for the moving mass part.

Diaphragm printed in PLA, using a Cura's "Spiralize Outer Contour" mode.

Dust Cap printed with PLA, flat design.

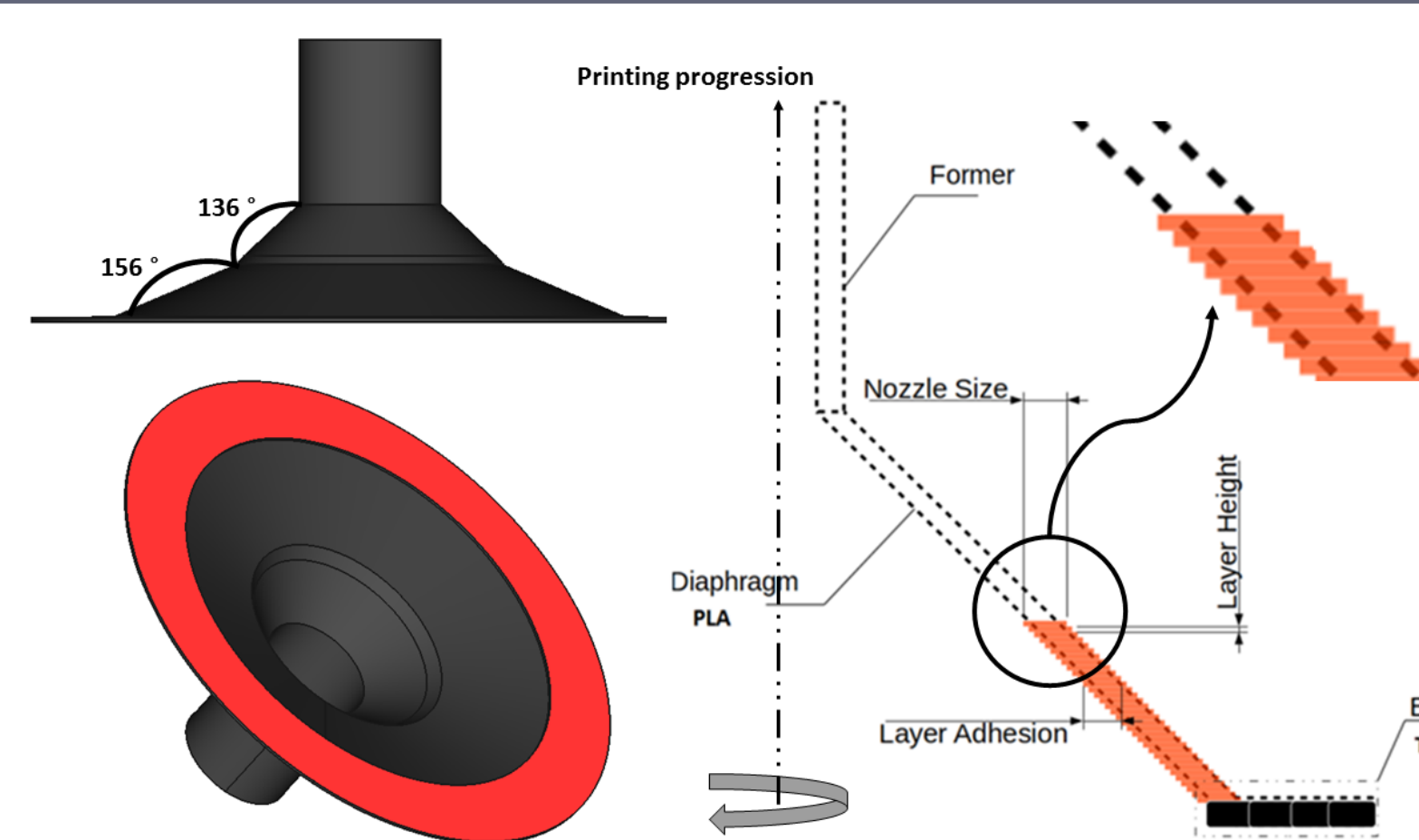
Spider suspension printed in TPU at low speed.

Former printed in PLA as part of the moving mass design.

Coil not printed. Made of a few meters of metal wire.

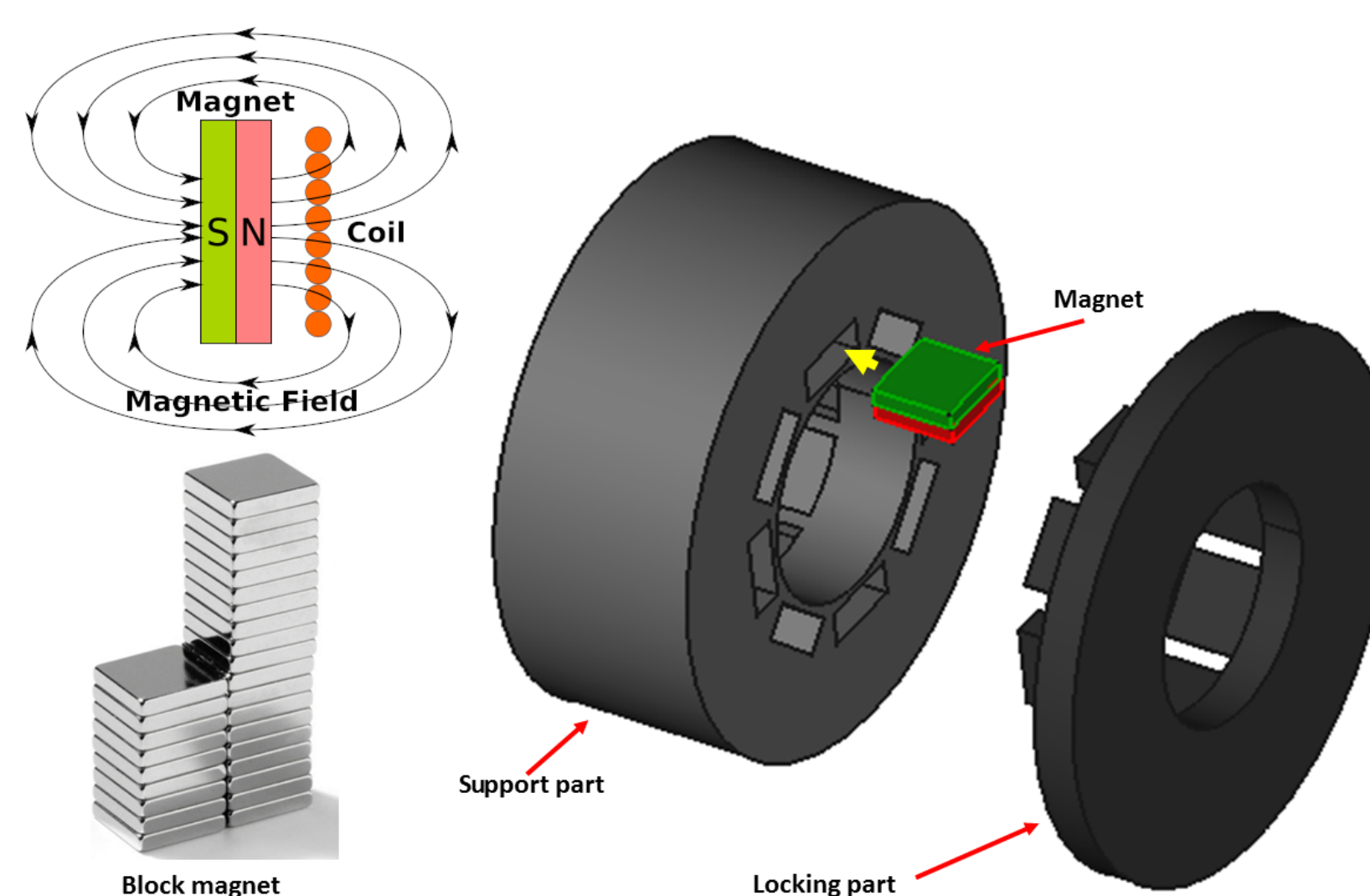
Magnetic motor: Specific ironless design printed in PLA. Requires several small permanent magnets.

MOVING MASS DESIGN



- Cura's "Spiralize Outer Contour" mode: empties the solid and prints only the outer edge as a spiral with increasing altitude.
- Nozzle diameter, layer height, and overhang angles are crucial parameters for a good layer adhesion.
- Result: light and air-tight part with smooth surface.
- Surround, diaphragm and former are printed together as a unique part.
- Surround is printed in TPU as a brim of the diaphragm, printed in PLA.
- Filament material is changed manually during printing.
- Neither glue, nor part centering procedure required.

IRONLESS MOTOR DESIGN



- Printing polar circuit parts is a demanding procedure [2].
- Ironless design: create a permanent radial magnetic field by using several block magnets.
- The magnets are arranged in a circular pattern with their polarity directed towards the center.
- Holding frame designed and printed in PLA.

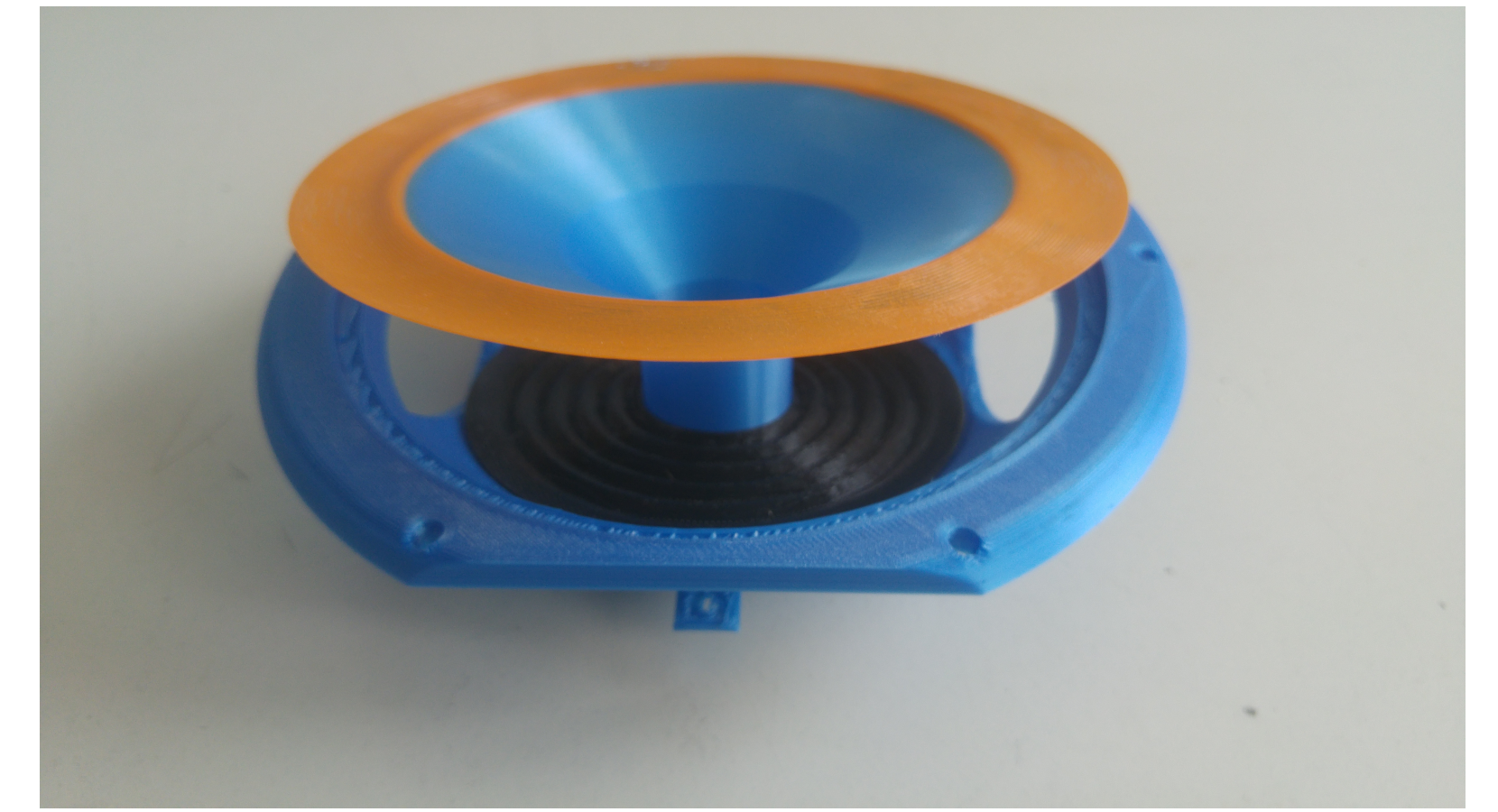
CONCLUSION & FUTURES WORKS

- Functional prototype shows promising results for a very low budget project (≤ 15 €).
- Magnetic motor improvements: higher block magnets to reduce magnetic field short-circuits.
- Parts design improvement: CAD designs allowing to get rid of the supports during printing and glue during assembly.
- Mechanical properties improvements: Use of composite filaments such as PLA-carbon fiber.
- All the CAD files, assembly instructions and documentation are available online: <https://github.com/dr-mxusse/3d.printed.loudspeaker>

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ASSEMBLY



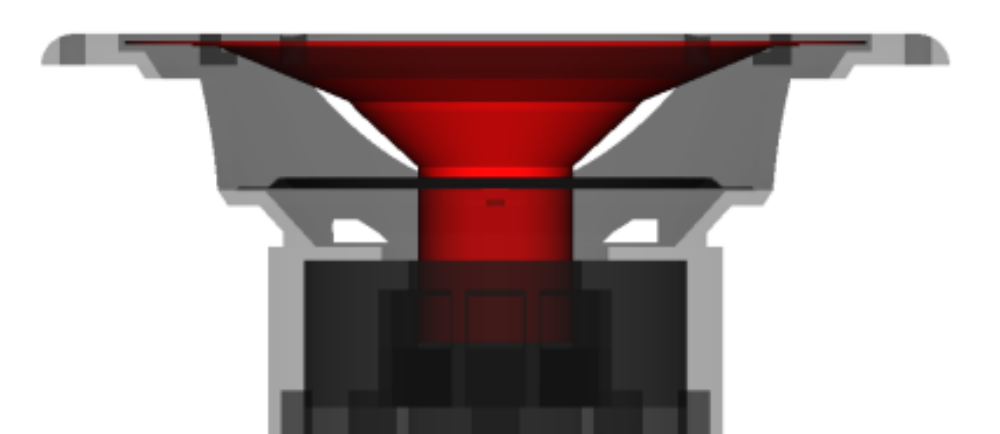
- The surround is glued to the chassis.
- The spider is glued to the former and to the chassis.
- The voice coil is wound on the former with a winding machine.
- A wooden cabinet is built for the prototype.



FIRST PROTOTYPE MEASUREMENTS

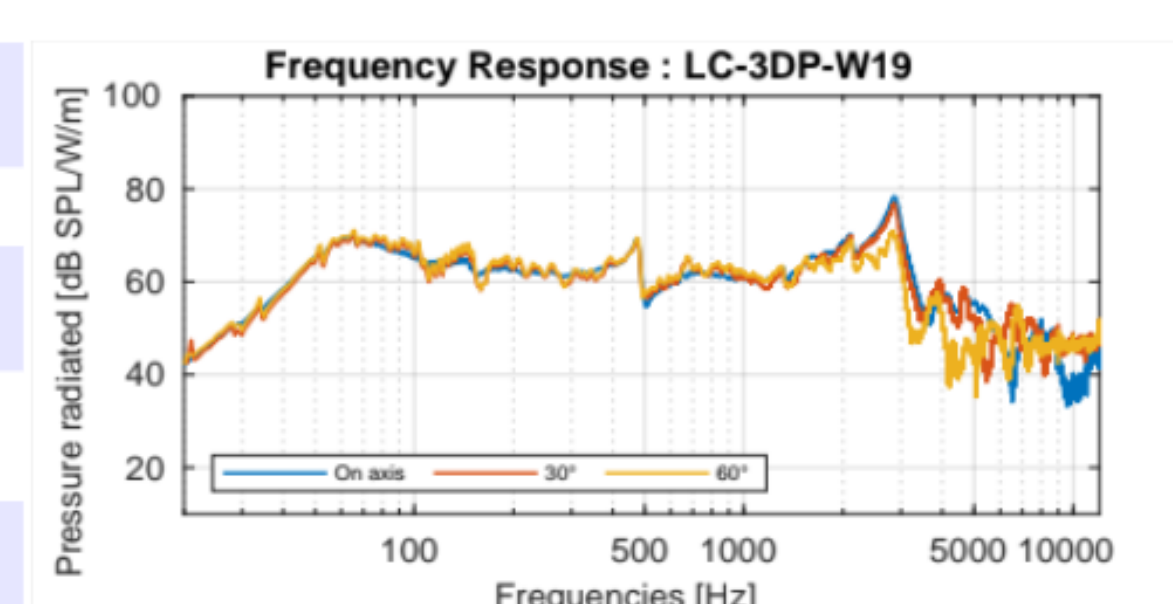
- Thiele & Small parameters estimated.
- Frequency response measured on axis and at 30°, 60°.

LC-3DP-W19: 3D Printed Loudspeaker



General Specifications

Nominal Impedance	8 Ω
Sensitivity	61 dB/W/m @ 1kHz
Bandwidth	[40-3k] @ 6 dB
Voice coil inner diameter	24 mm
Voice coil material	Aluminum (ø 0.214 mm)
Diaphragm material	Polyactic Acid
Surround / Spider material	TPU
Total mass	149 g



Thiele and Small Parameters

S_d	95 cm ²	f_s	66.5 Hz
M_{ms}	17 g	Q_{es}	103
C_{ms}	3.37×10^{-4} m/M	Q_{ms}	2.25
R_{ms}	3.15 N.s/m	Q_{ts}	2.2
L_e	0.485 mH	V_{as}	4.3 L
R_e	9.5 Ω	η_0	1.2 %
Bl	0.8 T.m		

