From Script to Print: Horn Design and Fabrication

Author Maximilian Ardalan Bernhard

Institutions FH Joanneum, KUG

Course Design & Research 2

Date 2026-08-31

1. Tractrix Horn Script

Modelling the horn contour wouldn't be viable sense to do via an expression, especially in the context of a prototyping phase. The sensible approach is to let a script evaluate the curve at discrete points and assemble a printable solid, using the calculated expression as the inner wall and adding an outer wall by providing the wall thickness via a parameter.

Providing the geometry as a parameterized script means that almost any experimental variable can be changed and regenerated in seconds rather than being chased through a hand-built model. In a project whose whole point is to compare horn contours and observe how the room's response changes, this parametric control is not a convenience but a prerequisite. The script turns the horn from a fixed design into something adjustable, so that the influence of a dimension on the reflected sound can be isolated and tested experimentally instead of assumed.

The contour is generated by a Python script running inside Blender. The script evaluates the tractrix parametric equation at discrete values to produce mesh vertices, then turns them into a three-dimensional surface. One detail matters for the acoustics: the wall thickness is placed outside the original contour, so that the inner surface the sound actually encounters follows the tractrix exactly. It would be easy to offset the wall inward and subtly change the profile the sound sees; placing the thickness outward keeps the mathematical contour intact as the acoustic boundary.

The script writes its output directly as an STL file, ready for the slicer, and it is accompanied by an explanation document covering the underlying mathematics and the integration with Blender, so that the generation is reproducible and not opaque.

The geometry itself is defined by a small set of parameters. The mouth diameter and the throat diameter can be entered directly, or, where a specific low-frequency cutoff is wanted, the throat diameter can be combined with a target cutoff frequency instead. The script then derives the corresponding mouth geometry and constructs the full contour. A further parameter controls the wall thickness, and the resolution of the discretization can be adjusted to trade mesh smoothness against file size and printing time.

Writing the mesh-generation and Python scripting for Blender was beyond what I could have solved alone within the timeframe of the project. An AI assistant helped structure and debug the script. The acoustic and mathematical decisions, however — which parameters matter, how the cutoff should be derived from the mouth, what the horn must load — were made and verified by hand, so the tooling never silently overruled the design intent.

The tractrix geometry itself has a long and specific lineage. The curve was studied as early as 1690 by Christiaan Huygens, and its application to loudspeaker horns was patented by Paul Voigt in 1927 (Voigt 1927). It earns its place here by producing a low-distortion, nearly spherical wavefront of constant radius: ideally, as Kolbrek's introduction to horn theory describes, all parts of the contour radiate in phase, as if spreading from a point source (Kolbrek 2008). That property matters inside a live feedback loop, where added nonlinearity would compound over repeated generations rather than staying contained.

2. Three-Dimensional Modelling

The raw tractrix mesh is only the acoustic body of the horn. Turning it into something that can be mounted on a gimbal and driven by a servo requires a second stage of modelling, in which the mounting hardware is added around the contour.

For the loudspeaker horn, the script-generated mesh was refined to include axle mounts for the gimbal pivot and an inset at the mouth, so that the loudspeaker driver slots in from the front and is held cleanly in place. The overall size was chosen against a hard constraint: the 3D printer bed measures 300 millimetres across, so the horn mouth was kept to 280 millimetres in diameter, leaving a small margin. The throat's diameter, on the other side, is set by the driver it must fit.

The microphone horn was designed with a different guiding principle. Instead of maximizing the mouth within the bed, it was sized for a cutoff frequency of 800 Hz. A horn acts as an acoustic impedance transformer, coupling the high-pressure motion of a small diaphragm to the low-pressure motion of the surrounding air (Beranek and Mellow 2019; Kolbrek 2008) — the framing under which Beranek and Kolbrek analyse horns and their directivity. Below a horn's cutoff the mouth no longer loads the driver effectively, while above it the horn becomes increasingly directional, which is the very directivity the installation exploits. The cutoff is set by the circumference of the mouth, and choosing 800 Hz was a decision about the sound material the installation is meant to work with, meaning the frequencies the horn should capture and radiate. Because it was sized by cutoff rather than by the bed's maximum dimension, it ended up smaller than the loudspeaker horn.

Both gimbals needed a way to attach to a standard microphone stand. A base plate was modelled as a microphone-stand adapter, mounting to a standard 3/8-inch thread and housing both the pan and tilt axes of the gimbal.

Center of gravity received particular attention. A gimbal driven by small servomotors must be reasonably balanced, otherwise the motors work against gravity and their effective stiffness drops. To give the mechanism some forgiveness, the servo does not drive the gimbal axis directly; instead, the force is transferred over a thin iron-wire strut. The compliance of this strut absorbs brief mechanical shocks and helps protect the servos from inertia when the gimbal changes direction, reducing the risk of stalling on a mechanical binding. It also makes the assembly less sensitive to small misalignments between the servo and the pivot, which is valuable when every part is a fresh print.

A shortfall of the pipeline deserves an honest note here: the mounting points, such as the gimbal bracket, still had to be modelled by hand rather than generated by the script. It would be a clean improvement to compute these mounts automatically from the pivot point and the center of mass, and to regenerate them alongside the contour. Within the timeframe, though, the manual approach of adding the mounts to the finally chosen 3D models was the pragmatic one.

3. 3D Printing and Iterative Refinement

With the models complete, the parts moved to the printer. The loudspeaker horn and the first mounting bracket were printed first. Unsurprisingly for the first attempt, the bracket immediately exposed a problem: the servo fittings had been modelled too tight, so the servos did not sit correctly in their mounts. The bracket had to be redrawn and reprinted.

This is the central lesson of digital fabrication for a one-off prototype. Tolerances are not guaranteed by the model alone; they depend on the printer, the material shrinkage, and the way each layer settles. A part printed fresh almost never fits perfectly the first time, and every design error costs a full reprint cycle, in the case of the loudspeaker horn it would have taken 8 hours to reprint, which in a project on a tight timeline is the scarcest resource of all.

The microphone horn and the final stand adapter followed. These parts were printed with the benefit of the earlier lessons, and the iterative loop of model, print, inspect, and revise ran more smoothly as a result.

The mechanical trust and the printer itself came from my father, who assisted significantly with the 3D modelling of the parts and brought printing expertise to the process. It is one of those contributions that is easy to understate in a project summary: the difference between having access to someone who can turn an STL into a robust physical part, and having to learn the whole craft of printing under time pressure, is the difference between a few reprint cycles and many. So, thanks to him it all worked out in the time frame I had, danke Papa!

Bibliography

Beranek, Leo Leroy, and Tim J. Mellow. 2019. *Acoustics: Sound Fields, Transducers and Vibration.* Second edition. Academic Press.

Kolbrek, Bjørn. 2008. *Horn Theory: An Introduction, Part 1.*

Voigt. 1927. Improvements in Horns for Acoustic Instruments. Patent. Patent, issued October 5, 1927.