Designing an Enclosure for a Micro Speaker

A micro speaker's datasheet response is measured in a test baffle, not in your product. Once you mount it, the enclosure becomes part of the speaker: the air behind it sets the bass, the cavity and port in front of it shape the treble, and every leak or rattle shows up in the sound.

This guide walks through those effects in the order they matter: separating front from back, sizing the back volume, tuning the front cavity and port, sealing and mounting, protecting the port, and the mechanical details that cause buzz. It ends with a checklist for prototyping and measurement.

Front and back cavities, and why the seal between them matters most

A speaker diaphragm pushes air forward and pulls it backward at the same moment, so the sound from its back is the inverse of the sound from its front. If the two meet, they cancel. This "acoustic short circuit" is strongest at low frequencies, where the wavelength is long compared with the speaker, and it is why a bare micro speaker on a bench sounds thin.

Every micro speaker enclosure therefore has two separate air spaces:

- **The front cavity** is the small space between the diaphragm and the product's outer wall, connected to the outside by a sound port.
- **The back cavity** (or back volume) is the sealed space behind the speaker.

The single most important rule is that no air path should connect the two. A gap of a fraction of a millimetre around the speaker's rim can cost several decibels of low-frequency output, more than most tuning choices gain.

Back volume: how it sets the bass

The air trapped behind the speaker acts as a spring. The smaller the volume, the stiffer the spring, and the higher the frequency where bass output starts to roll off. For a sealed back cavity, the system resonance rises from the speaker's free-air resonance f_s to:

$$f_c = f_s \sqrt{(1 + V_{as} / V_b)}$$

Here V_{as} is the speaker's equivalent compliance volume and V_b is the net air volume of the back cavity. The same factor multiplies the speaker's Q, so a cramped back volume also makes the response peakier around f_c.

For a micro speaker with f_s = 800 Hz and V_{as} = 2 cm³:

Back volume V_b (cm³)	Resonance f_c (Hz)
0.5	1790
1	1390
2	1130
4	980

The returns diminish quickly. Doubling the back volume from 0.5 to 1 cm³ lowers f_c by 400 Hz; doubling again from 2 to 4 cm³ gains only 150 Hz. Size the back volume to where the curve flattens, not to whatever space is left over.

Practical points:

- **Use net volume.** Subtract the space taken by the speaker's magnet, PCBs, cables and screw bosses.
- **Check the datasheet's test condition.** Many micro speaker datasheets state the back volume used for the published response, for example "measured in a 1 cc enclosure". If your design is smaller, expect less bass than the graph shows.
- **Acoustic absorbers can help.** Open-cell foam or specialist absorbing materials in the back cavity damp internal resonances and can make the volume behave as if it were somewhat larger.
- **Pressure equalization needs care.** If the product must breathe for altitude or temperature changes, use a vent with high acoustic resistance, such as a microporous membrane, so it doesn't act as a leak at audio frequencies.

Front cavity and sound port: tuning the treble

The air in the front cavity acts as a spring and the air in the sound port acts as a mass. Together they form a Helmholtz resonator, like blowing across a bottle. Output rises to a peak at its resonant frequency and then falls off steeply above it, so this resonance sets the useful upper limit of the speaker in your product.

$$f_H = (c / 2\pi) \sqrt{(A / (V_f L_{eff}))}$$

Here c is the speed of sound (343 m/s), A is the total port area, V_f is the front cavity volume, and L_{eff} is the effective port length: the wall thickness plus an end correction of roughly 1.7 × the port radius for a short round hole.

Worked example. A 0.1 cm³ front cavity with one 2 mm diameter port through a 1 mm wall gives A = 3.14 mm², L_{eff} = 1 + 1.7 × 1 = 2.7 mm, and f_H ≈ 5.9 kHz. Thicken the wall to 3 mm and f_H drops to about 4.4 kHz. Double the front cavity volume and f_H drops by a factor of √2.

Design guidance:

- **Keep the front cavity small.** A thin gasket and a speaker mounted close to the wall push f_H up and out of the way. A large front cavity is the most common cause of a muffled, honky sound.
- **Give the port enough area.** A common starting point is a total open area of 10 to 20% of the diaphragm's effective area. Smaller ports lower f_H and add flow resistance that reduces output.
- **Several small holes are not the same as one large one.** For the same total area, small holes have more viscous losses. That damps the resonance peak, which can be useful for a smoother response, but it also costs some level.
- **Watch wall thickness.** A port through a thick wall, or a long channel to reach the outside, behaves like a longer neck and lowers f_H.
- **Place the port where it won't be blocked.** Ports on the bottom of a device that sits on a table, or where a hand naturally rests, change the sound in real use.

Sealing, gaskets and mounting

The gasket does two jobs: it seals front from back, and it sets the height of the front cavity. Choose it with both in mind.

- **Seal on the speaker's frame, never on the diaphragm or surround.** Pressing on the moving parts changes the response and can cause distortion or failure.
- **Use a compliant, closed-cell gasket.** Closed-cell foam or silicone conforms to molding tolerances and blocks air. Open-cell foam leaks. Double-sided adhesive foam rings are a common, cheap solution for small speakers.
- **Compress it the right amount.** Too little compression leaves gaps at the corners; too much distorts the speaker frame. Follow the gasket supplier's recommended compression range, often around 20 to 40%.
- **Seal the back cavity as carefully as the front.** Cable exits, screw holes, button openings and housing seams are all leak paths. Route wires through a sealed slot or pot them.
- **Hold the speaker positively.** Ribs, a pocket or a retaining bracket should keep it from shifting under drop and vibration. A speaker that can move a little will eventually rattle.

A simple leak test is to listen to a low tone (say 300 to 500 Hz) while gently pressing the housing seams. If the level or tone changes when you press, there's a leak.

Protecting the port: mesh, membranes and water resistance

Anything placed over the sound port adds acoustic resistance or mass, so include it in the design from the start rather than adding it late.

Protection	Keeps out	Acoustic effect	Typical use
Acoustic mesh (woven polyester or nylon)	Dust and debris	Small loss; can smooth the front-cavity peak	Most consumer products
Metal grille	Fingers, tools	Negligible if the open area is large	Rugged or exposed ports
Waterproof acoustic membrane (e.g. ePTFE)	Water and dust, for IP67-class designs	Several dB loss, mostly at high frequencies; adds mass that lowers f_H	Wearables, outdoor and wet-environment devices

Tips:

- **Pick mesh by its rated acoustic resistance**, given in rayls, not by its thread count. Suppliers publish this figure, and it lets you predict the effect.
- **Mount membranes flat and unstretched**, with adhesive only around the edge. A membrane that touches the grille or the diaphragm will buzz.
- **Remember that waterproof designs still need to equalize pressure.** A sealed speaker behind a membrane can be pushed out of position by altitude or temperature changes. Use a separate vent membrane for the housing.
- **Re-check the Helmholtz tuning** once the protection is in place, since its added mass acts like a longer port.

Mechanical details: stiffness, rattles, damping and microphones

Most complaints about micro speaker sound in a finished product are mechanical, not acoustic.

- **Make the walls stiff.** Thin, flat panels around the back cavity flex and radiate their own sound, often as a dull boom or a buzz at one frequency. Add ribs, curve the surface, or thicken the wall near the speaker.
- **Hunt down loose parts.** Cables, flex circuits, labels and battery contacts inside the back cavity can rattle at high levels. Tape or clip them down.
- **Keep drive level within limits.** Overdriving a micro speaker makes the diaphragm hit its limits, which sounds like a rattle. Respect the datasheet's rated power and excursion, and use a high-pass filter in the amplifier or DSP to keep energy below f_c out of the speaker.
- **Damp internal resonances.** In larger back cavities, standing waves can cause narrow peaks. A small piece of open-cell foam opposite the speaker usually fixes them.
- **Separate the speaker from microphones.** In devices with voice pickup, sound and vibration from the speaker reach the microphone through the air and through the housing. Put distance between them, mount the speaker on soft gaskets, and point the speaker and microphone ports in different directions. Echo cancellation works much better when the acoustic coupling is low to begin with.

Prototype and measure: a design checklist

Calculations get you close, but the enclosure always needs measuring. 3D-printed housings are good enough for early acoustic testing if the walls are thick and the seams are sealed; Soberton publishes 3D-printable enclosure designs for many of its speakers as a starting point.

- ☐ Read the speaker datasheet's test conditions: drive level, measurement distance and the back volume used
- ☐ Seal the front cavity from the back cavity all the way around the speaker frame
- ☐ Calculate net back volume and estimate f_c
- ☐ Calculate the front-cavity Helmholtz frequency f_H, including any mesh or membrane
- ☐ Check that the port area is at least 10 to 20% of the diaphragm's effective area
- ☐ Place the port where hands and surfaces won't block it
- ☐ Seal every back-cavity leak path: cable exits, seams, screw holes, buttons
- ☐ Secure cables and loose parts inside the housing
- ☐ Measure the frequency response in the housing at the datasheet distance and compare it with the datasheet curve
- ☐ Sweep slowly at full rated power and listen for buzzes and rattles
- ☐ Check speaker-to-microphone coupling if the product has voice pickup

If the measured response falls short, check in this order: leaks first, then front-cavity size and port area, then back volume. That is usually the order of how much each one costs.

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