Speaker Enclosure Volume Calculation

Speaker enclosure volume calculation finds the air volume a speaker needs behind it to reach a target low-frequency response, or predicts the response you'll get from the space you have. For a sealed enclosure it comes down to one relationship between the speaker's free-air resonance fs, its compliance volume Vas, and the box volume Vb:

$$fc = fs \times \sqrt{(1 + Vas / Vb)}$$

This article explains where that formula comes from, which datasheet parameters you need, how to size a sealed or ported enclosure step by step, and how to turn the answer into a real, net air volume in your product. The examples use micro speakers, but the same equations apply to woofers.

Why box volume changes the sound

A speaker's moving parts behave like a mass on a spring. The diaphragm and voice coil are the mass; the surround and spider (or, in a micro speaker, the diaphragm's own suspension) are the spring. That system resonates at fs, and below fs the output falls away.

Close the back of the speaker in a box and the trapped air becomes a second spring working alongside the suspension. A smaller box means stiffer air, a stiffer combined spring, and a higher resonance. So the box volume directly sets how low the speaker can play.

The box also changes how sharply the response peaks near resonance, described by its Q. A box that is too small gives a high Q: a bump in output just above resonance and a boomy, ringing sound. A box that is large gives a low Q: a smoother, gentler roll-off but less output near resonance. Sizing an enclosure is choosing the balance between those two.

The parameters you need

The calculation uses three Thiele-Small parameters from the speaker datasheet.

Parameter	Meaning	Typical micro speaker	Typical 6.5 in woofer
fs	Free-air resonance, Hz	500–1000 Hz	30–60 Hz
Qts	Total Q of the speaker in free air	0.4–1.0	0.3–0.5
Vas	Air volume with the same stiffness as the suspension	0.5–5 cm³	10–30 L

Keep units consistent: Vas and Vb must be in the same units, so convert litres to cm³ (1 L = 1000 cm³) if needed.

If the datasheet doesn't give Vas

Micro speaker datasheets often list fs but not Vas. You can measure it with an impedance analyzer (or a signal generator, a series resistor and a voltmeter) and a small sealed test box of known volume Vt:

1. Measure fs: the frequency of the impedance peak with the speaker in free air.
2. Seal the speaker onto the test box and measure the new impedance peak, fct.
3. Calculate $Vas \approx Vt \times ((fct / fs)^2 - 1)$.

The added-mass method is an alternative: attach a small known mass to the diaphragm,

measure how far fs drops, and calculate the suspension compliance from that. It needs the diaphragm's effective area, which is hard to determine on very small speakers, so the test-box method is usually easier for micro speakers.

Sealed enclosure: step by step

A sealed box raises both the resonance and the Q by the same factor, α = Vas / Vb:

$$fc = fs \times \sqrt{(1 + \alpha)} \quad Qtc = Qts \times \sqrt{(1 + \alpha)}$$

Rearranged, you can start from the Q you want and get the volume you need:

$$Vb = Vas / ((Qtc / Qts)^2 - 1)$$

Choosing a target Qtc

Target Qtc	Character	Volume for the example below	Resulting fc
0.577	Smoothest transient response, gentle roll-off	3.1 cm³	1030 Hz
0.707	Flattest frequency response; the usual default	1.36 cm³	1260 Hz
1.0	About 1.2 dB peak near fc; more output, slightly boomy	0.51 cm³	1780 Hz

A Qtc of 0.707 is the standard starting point. Products with very little space often end up nearer 1.0, and that's acceptable if the peak is tamed with EQ.

Worked example

Take a micro speaker with fs = 800 Hz, Qts = 0.45 and Vas = 2 cm³, and aim for Qtc = 0.707.

1. Ratio of Q values: 0.707 / 0.45 = 1.571.
2. Square it and subtract 1: $1.571^2 - 1 = 1.468$.
3. Required volume: Vb = 2 / 1.468 = 1.36 cm³.
4. Resulting resonance: fc = 800 × 1.571 = 1260 Hz.

If the product only has room for 1 cm³, work the other way: α = 2 / 1 = 2, √3 = 1.73, so fc = 1390 Hz and Qtc = 0.78. That's a small, usually acceptable shift.

One check before you go further: if Qts is already above about 0.7, no sealed box can reach Qtc = 0.707, because the box only ever raises Q. Choose a speaker with lower Qts, accept a higher Qtc, or flatten the peak electronically.

Ported enclosure: tuning the port

A ported (bass-reflex) box adds a tube that lets the air inside resonate at a tuning frequency Fb, reinforcing the speaker's output near and below its own resonance. It extends bass further than a sealed box of the same size, at the cost of a steeper roll-off below Fb and a more complex design. Ported boxes generally suit speakers with a lower Qts, roughly below 0.4; micro speakers in compact products almost always use a sealed back cavity.

Choosing the box volume and Fb together (the "alignment") depends on all three Thiele-Small parameters and is best done in modeling software. Once you have them, the port is a Helmholtz resonator, and its effective length follows from:

$$Leff = (c^2 \times A) / (4\pi^2 \times Fb^2 \times Vb)$$

Here c = 343 m/s, A is the port's cross-sectional area, and Vb is the box volume, all in SI units. The physical tube is shorter than Leff by the end corrections, roughly 1.5 × the port radius for a typical round port flush with the baffle at one end.

Worked example. A 20 L box tuned to 40 Hz with a 5 cm diameter port: A = 1.96×10^{-3} m², so Leff = 0.183 m. Subtract 1.5 × 2.5 cm and the physical port is about 14.6 cm long.

Make the port large enough in diameter. A narrow port forces air through at high speed, which causes audible chuffing at high volume. If the required length won't fit, a slot port or a flared port is the usual fix.

Net volume, displacement and damping material

The Vb in every formula above is the net air volume, not the size of the box. To get from one to the other:

- **Start with the internal volume.** In CAD, model the inside of the cavity as a solid and read its volume. For a rectangular box, multiply the internal dimensions, not the external ones.
- **Subtract everything inside it.** The speaker's magnet and frame behind the mounting plane, PCBs, batteries, cables, bosses, ribs and bracing all take up air. In a compact product these can easily remove a third of the cavity.
- **For ported boxes, subtract the port too.** The tube's own volume sits inside the box.
- **Check a prototype.** For larger boxes, fill the cavity with dry sand, rice or water and measure what it holds. For micro speakers, measure the in-box resonance fc and work backward with the sealed-box formula.

Damping material changes the result slightly. Fiber filling or foam in a sealed box slows the air's pressure changes, which makes the box behave as if it were somewhat larger, often by roughly 10 to 20%. It also absorbs internal reflections that cause narrow peaks. Account for it by measuring fc with the filling in place, and treat any gain as a bonus rather than designing around it.

Putting it together

1. Get fs, Qts and Vas from the datasheet, or measure Vas with a test box.
2. Decide between sealed and ported. For micro speakers and most compact products, choose sealed.
3. Pick a target Qtc (0.707 is the usual default) and calculate the required Vb.
4. Check the fc that volume gives, and whether it meets your low-frequency target.
5. Compare the required Vb with the net volume your product can provide, and recalculate fc and Qtc for the volume you actually have.
6. Build a prototype, measure fc in the enclosure, and adjust.

For anything beyond a basic sealed box, free modeling tools such as WinISD or VituixCAD plot the full predicted response from the same parameters, including ported alignments, port air velocity and excursion limits. The formulas here are still worth knowing: they tell you quickly whether a design is in the right range before you open the software.

Soberton datasheets list the acoustic test conditions for each speaker, and our support pages cover enclosure design for micro speakers in more detail, including front-cavity and sound-port tuning.

Drafted with AI assistance and reviewed by Soberton engineering