

Technology

Why the crossover transition region is so sensitive

In the transition region of a crossover, both drivers – for example woofer and tweeter – are active at the same time. Exactly here the fine interplay of level and phase decides whether the summed result is calm, stable in imaging and natural – or whether soundstage, localisation and sibilants become “nervous”. Both Macro-microphony (movement of windings/foils) and Micro-microphony (very small, material internal effects) can create timevarying minichanges in component values. In the transition region such Micro-modulations have a disproportionate effect, because two sources are summing simultaneously, phase is rotating steeply around the crossover frequency, and directivity (lobing) reacts very sensitively.

Crossover transition

What really happens in the transition region

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What really happens in the transition region

Beyond Ohm's law (R), the reactive parts dominate around the crossover frequency:

- **Inductor:** reactance $X_L = 2\pi f \cdot L$ – the larger L , the stronger the "resistance" to rapid changes in current.
- **Capacitor:** reactance $X_C = 2\pi f \cdot C$ – the larger C , the more easily current flows at higher frequencies.

The crossover frequency (simplified for a secondorder LC filter) is $f_c \approx \frac{1}{2\pi \sqrt{L \cdot C}}$

Small timedependent fluctuations of $L(t)$ or $C(t)$ – whether from macro or Micro-microphony – shift this f_c slightly. A useful approximation:

$$\frac{\Delta f_c}{f_c} \approx -\frac{1}{2} \left(\frac{\Delta L}{L} + \frac{\Delta C}{C} \right)$$

In words: when L or C "breathe", the crossover frequency breathes with them.

These tiny shifts are amplified in three ways:

1. **Double source:** Around f_c both drivers are active. Changes of a few tenths of a dB per branch noticeably alter the summed response.
2. **Steep phase rotation:** Filters rotate phase rapidly around f_c . A small Δf_c produces a perceptible phase shift → the addition pattern changes audibly.
3. **Directivity (lobing):** As soon as the phase relationship wobbles, the main lobe of the radiation moves. This leads to an unstable soundstage, wandering localisation and glassy sibilants.

A simple numerical example

At $f_c = 2$ kHz, a change of $\Delta C/C = +0.5\%$ already causes approximately $\Delta f_c/f_c \approx -0.25\%$, i.e. about 5 Hz. That sounds small, but because of the steep phase rotation around f_c it can be enough to shift the summed response by tenths of a dB, noticeably change localisation and sibilants, and create combfilter effects.

How Macro- and Micro-microphony feed into this

- **Macro-microphony:** movement of conductors/foils under field forces generates induced voltages and timevarying $L(t)/C(t)$ – the filter behaviour is modulated.
- **Micro-microphony:** material effects (e.g. piezo/electrostrictive micromotions, dielectric relaxation) generate very small but continuous $\Delta L/L$ and $\Delta C/C$ as well as subtle noise components.

In the transition region both add up: macro sets the moving framework, micro fills it in across the band. Together they shift level, phase and Qfactor of the branches – exactly where the ear is most sensitive.

Conclusion – and how the effects works together

The transition region is the acoustic focal point of the crossover. Here, time varying component values – whether from macro or Micro-microphony – have an oversized impact, because summation, phase and directivity are all sensitive at once. That's why the chapters on macromicrophony and Micro-microphony point back to this section: it explains why small modulations have such a large effect right here – and why structural calm and materially stable components in the transition region audibly unlock more music.

Key takeaways:

- When L or C breathe, the crossover frequency breathes with them.
- Where two drivers sum, phase becomes a matter of prime importance.
- Calm structure = calm sum.
- In the transition region, the truth comes out.
- No modulation, no nervousness – just music.
- Macro moves components, micro moves materials – both shift level, phase and Q right in the hotspot.