Damping – General Guide

(iPhone/iPad/Android App Documentation)

Version 1.005

28. huhtikuuta 2025

Change Log

Date	Version	Change
27.4.2025	1.005	The operating-principle text has been updated.

Date	Version	Change
10.3.2025	1.004	Images and related explanations removed

Date	Version	Change
8.3.2025	1.003	Image captions updated

Date	Version	Change
7.3.2025	1.002	Minor changes to image layout

Date	Version	Change
6.3.2025	1.001	Added instructions for making a cylindrical leather foot

Date	Version	Change
28.2.2025	1.0	First release

Table of Contents

Sisällys

1 Explanation of Terms

1.1 Tärinä, värinä, värähtely, mikrovärähtely (vibration, oscillation, microvibration):

1.1.1 Terms describing the intensity of vibration

- **Distortion (särö, vääristymä):**
  Anything that changes something in the original signal other than amplitude.
- **Noise (häiriö):**
  Undesired, randomly introduced extra electrical or electromagnetic energy that degrades the signal and the data it carries.
- **Harmonic distortion (Harmoninen särö):**
  Unwanted sounds that occur when vibration adds extra frequencies to the signal.
- **Microphony (mikrofonismi):**
  A phenomenon in which components convert vibration into an audio signal.
- **Resonance (resonanssi):**
  A vibration at a certain frequency that is amplified due to its natural resonant frequency.
- **"Singing" capacitor (Laulava kondensaattori):**
  One cause of poor sound quality is a "singing" capacitor. The capacitor "sings" when the input signal's ripple current makes it vibrate due to a piezoelectric effect. The acoustic noise does not originate directly from the vibrating capacitor, but indirectly when the capacitor makes the circuit board (PCB) vibrate.

1.1.2 Vibration Control

In audio reproduction, isolation, decoupling, coupling, damping, and dissipation each work in their own way, yet they are also interrelated in controlling vibrations and optimizing sound quality. Below is a description of how each method functions and their core mechanisms:

- **Isolation (Eristys):**
  Reduces the transfer of external vibrations to the device. Uses soft, elastic materials, e.g., cork-rubber, silicone, sorbothane. For instance, steel balls in a bag or box with such materials in the bottom.
- **Decoupling (Irrotus):**
  Breaks the vibration transmission path in the unwanted direction. Materials or structures that separate components and reduce energy transfer. For example, steel balls in a bag/box with additional insulating materials like felt pads in the bottom.
- **Coupling (Kytkentä):**
  Transfers energy. Coupling to a surface reduces the device's internal resonance by

directing vibration into damping and dissipation. For instance, a bag of steel balls placed directly against the bottom of the device, without the device's original feet.

- **Damping (Vaimennus):**
  Absorbs and reduces resonances. Materials that specifically bind energy at resonant frequencies, preventing vibration from intensifying. For instance, steel balls in a bag or box.

- **Dissipation (Hajotus):**
  Disperses and converts vibrational energy. Materials and granules, e.g., balls, that absorb energy by converting it into heat and distributing it over a broader area. For instance, steel balls in a bag or box.

2 Vibration-Related Problems in Audio

Vibrations can cause a wide range of issues in audio devices, degrading sound quality and disrupting operation. Here are the main problems:

1. **Harmonic Distortion (Harmoninen särö)**

   Issue:
   Vibration can introduce extra harmonic frequencies not in the original sound. For example, the resonances of a speaker enclosure can add unwanted frequencies to the sound.

   Impact:
   The sound is perceived as inaccurate, unclear, and "distorted." Harmonic distortion can be especially significant at low frequencies, where vibrations typically occur.

2. **Noise (Kohina)**

   Issue:
   Mechanical vibrations can produce low-frequency noise that masks the original audio signal. For example, in a turntable, vibration can travel to the stylus, creating low-frequency hum or other interference.

   Impact:
   Noise can ruin the listening experience, particularly during quiet musical passages.

3. **Resonances (Resonanssit)**

   Issue:
   Audio device enclosures, shelves, or stands can resonate at certain frequencies, amplifying unwanted sounds. Speakers can transmit vibrations to the floor or walls, creating resonances in the room. The speaker cabinet's vibration can color the sound and affect the purity of reproduction.

   Impact:

Bass frequencies can become uneven and exaggerated. The entire frequency response may be distorted.

4. **Interference in Electronic Components (Sähköisten komponenttien häiriöt)**

   Issue:
   Vibration can affect the internal parts of audio devices, such as capacitors, coils, and circuit boards. This can cause instability, such as distortion or audio dropouts.

   Impact:
   The device's performance may degrade, and the sound may contain pops or other interference.

5. **Signal Degradation in Turntables (Signaalin huonontuminen levysoittimissa)**

   Issue:
   Vibration can affect the turntable stylus, causing it to fail to accurately follow the groove. This can increase both distortion and noise.

   Impact:
   The sound may be distorted and include extra sounds such as hum or vibration.

6. **Imprecision in Speaker Drivers (Kaiuttimen elementtien epätarkkuus)**

   Issue:
   Vibrations can transfer to the speaker drivers, disturbing their motion and degrading sound reproduction. The driver is supposed to move accurately according to the signal, but vibration can induce asymmetry or extra motions.

   Impact:
   Vibrations can cause inaccuracies in the bass reproduction, degrade imaging clarity, and increase noise. The soundstage may collapse, and the sound may lose definition.

7. **Acoustic Disruptions in the Listening Room (Akustiset häiriöt huonetilassa)**

   Issue:
   Vibrations from devices or furniture can affect room acoustics, adding irregularities in the reproduction of bass or other frequencies.

   Impact:
   The acoustic balance gets worse, and the music can sound less natural.

8. **Wear and Damage to Components (Komponenttien kuluminen ja vaurioituminen)**

   Issue:
   Long-term vibrations can cause mechanical wear inside audio devices. For instance, solder joints may loosen or crack.

   Impact:

The devices' lifespan is shortened, and repair needs increase.

9. **Microphonic Effect (Mikrofoniefekti, Microphony)**

   Issue:
   In some electronic components, such as tube amplifiers or capacitors, vibrations can cause a microphonic effect, converting vibrations into audio signals. For example, capacitor and inductor vibrations cause distortion in the audio signal. Vibration problems are especially troublesome in clock timing, distorting it, and thus carrying distortions through the entire audio system to the speakers and your ears.

   Impact:
   The sound may include unwanted "metallic" or "buzzing" tones.

10. **Psychoacoustic Effect (Psykoakustinen vaikutus)**

    Issue:
    Although vibration is not always directly audible, it can have a psychoacoustic effect: the listener perceives the sound as less pleasant or less enjoyable.

    Impact:
    The listening experience can be less engaging.

3 Introduction to Ball-Reservoir Damping

Balls in a reservoir provide an excellent solution for damping vibration in audio systems for multiple reasons. They effectively utilize the physical properties and dynamic behavior of materials for damping.

Key reasons include:

1. Suitable for adding mass.
   Why is this important?
   Increasing the mass lowers the vibration frequency, as a heavier structure is less prone to resonances.

2. Energy-dispersing effect of moving balls
   Why is this important?
   Vibrational energy is effectively dispersed and absorbed when individual balls move in the bag, and friction between them converts part of the energy into heat.

3. Wide usable frequency range
   Why is this important?
   Audio devices may vibrate at widely differing frequencies, and effective damping requires performance across multiple frequency ranges.

Ball-based damping does not add anything to the signal; it simply prevents its quality from degrading.

Ball-reservoir dampers are an effective and cost-efficient way to prevent undesired vibrations. They work for damping both vibrations generated by the devices themselves and those that come from outside (e.g., through the floor or furniture).

Likely perceived effects: Enhanced bass definition, improved volume dynamics, and newly revealed details. Vocals and instruments sound natural.

4 Underlying Theories

The operating principle of ball-reservoir dampers is based on fundamental physical phenomena such as vibrational energy and its conversion into heat. It applies numerous scientific studies and articles.

Keywords for search engines:

- Multi-unit particle dampers
- Multi-cavity particle dampers
- Multi-compartment particle dampers
- Multi-particle dampers
- Particle dampers
- Granular dampers
- Multi-unit granular dampers
- Shot dampers
- Bean Bag dampers

5 Operating Principle

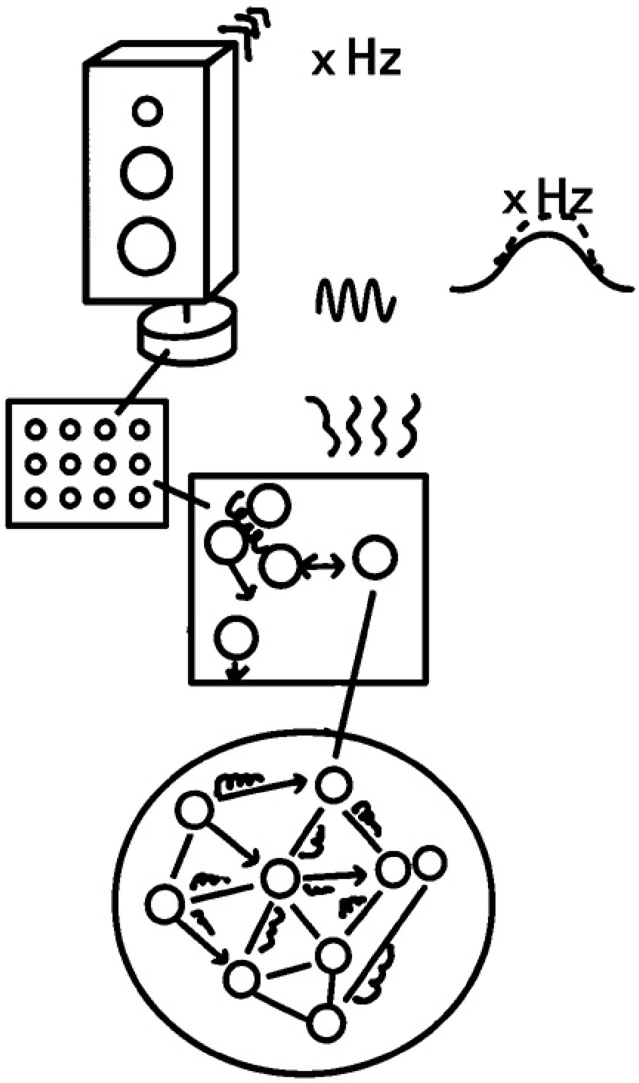
In physical terms, the process is based on a damped and forced oscillator (counter-vibration), which eliminates undesirable vibration in the form of a ball damper.

This desired counter-vibration depends on the parameters provided (the weight of the target to be damped, as well as the size and type of ball).

> If friction were too high, damping would occur immediately. Instead, we prefer not to have excessive friction, so that the balls allow the upper mass to vibrate freely and uniformly, yet with the vibration quickly damping out once no external energy is supplied.

Damping absorbs vibration, converting it into heat as the balls collide with and rub against each other and the container walls. The container size should allow the required number of balls to completely fill it. Damping for vibration is 360 degrees, horizontally and vertically, in every direction.

Especially the kinetic energy of vibrations at the resonance frequency and the nearby frequencies is converted into heat by various types of friction.



Kuva 1: Vibration is converted into heat.

Partially elastic collisions are a common phenomenon that occurs in many materials such as metals. This is because the internal structures of the material—atoms and molecules—are not perfectly ordered but somewhat disordered. When the balls collide, their internal structures shift into new positions, causing internal energy to turn into heat. The contribution of a single collision is small, yet collisions occur constantly in great numbers, in addition to the balls rubbing against each other.

In loudspeakers, and especially subwoofers, the external force acting on the damper is a low-frequency, high-energy vibration at the loudspeaker's resonance frequency; that vibration and the neighbouring frequencies are damped. Sound quality improves because the room and its contents do not start to resonate—at least not through the floor—and therefore do not indirectly affect the audio electronics.

In electronics, sound quality is improved by isolating the device from external vibrations coming from below and by damping the device's own resonance frequency and the surrounding nearby frequencies, preventing their harmful effects on internal components—for example, the "singing" (microphonics) of a capacitor. Note that vibration also reaches the device through cables.

6 Effects of Ball Dampers on the Target Device

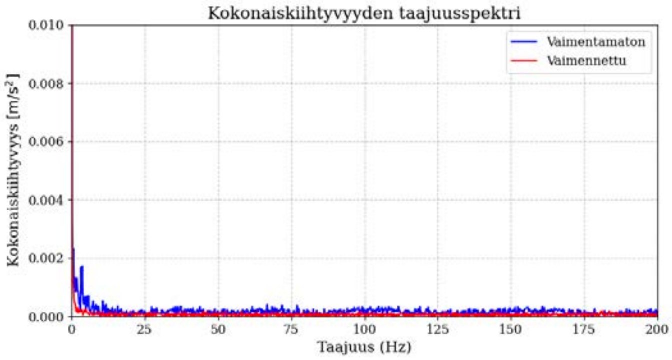
In speakers, damping has a positive effect on the cone, coil, and magnet, as well as any bass-reflex port. Moreover, vibration from the speaker cannot affect audio electronics through the listening room structures or equipment stand.

Microphony: Eliminates microphony, which is the phenomenon where certain electronic components (capacitors, inductors, wiring) convert unwanted vibration into undesired distortion signals.

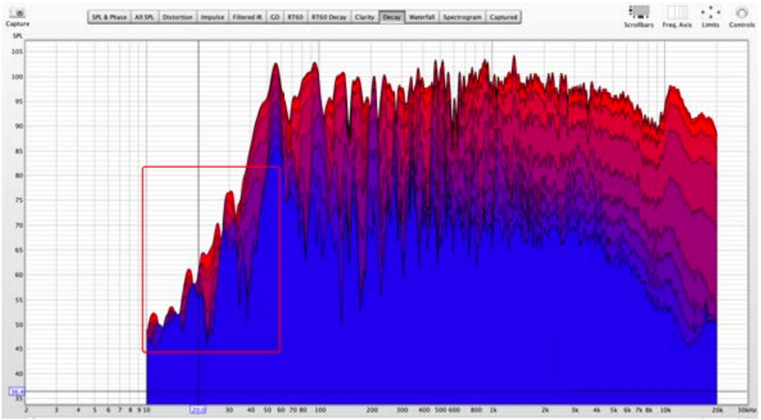
Reduces internally generated vibration: Every audio-electronic device creates or receives unwanted vibration. A ball damper helps absorb that unwanted vibration, converting it into heat.

6.1 Measurement Results

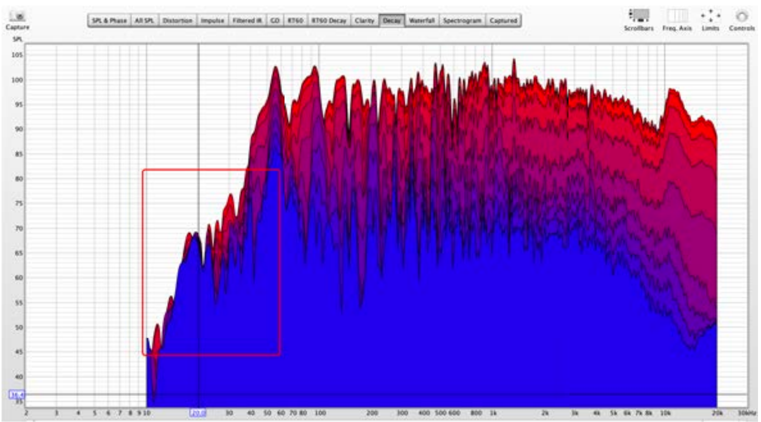
Based on the measurement data, damping (Figures 2 and 3) most significantly cuts peaks in the low and lower-midrange frequencies and speeds up the decay by a few dB, compared to the case with no mechanical damping (Figure 4). From Figures 2 and 3, one can see that harmful vibration is around 1/20 of what it is when using the DA converter's normal feet. REW-based measurements show the same: the decay is shorter especially at low frequencies, although there is an effect across the entire frequency range (Figure 4).



Kuva 2: Effect of Hi-Fi Damping dampers on the vibration of an RME ADI 2/4 Pro SE DA/AD converter.



Kuva 3: Decay when damped: REW measurement using a microphone, showing the effect of Hi-Fi Damping dampers on an RME ADI 2/4 Pro SE DA/AD converter.



Kuva 4: Decay when undamped: REW measurement using a microphone, showing the effect of Hi-Fi Damping dampers on an RME ADI 2/4 Pro SE DA/AD converter.

7 Materials and Supplies

If you want to make the containers yourself, note the following:

- **Cotton and leather:** they do not become charged electrically, so use them.
- **Fabric:** cotton (e.g. canvas) sturdy enough.
- **Leather:** preferably thin so that it is flexible and can be sewn with a regular sewing machine.
- **Sewing supplies:** hand-sewing leather needle, a cutting leather needle for machine sewing, stretchy nylon thread, drafting or graph paper, a marking pencil, zipper, Velcro tape.

Balls:
Bright precision balls, such as 4.5 mm or 5.0 mm steel BBs for airguns, easily available and inexpensive.

Other:
A digital scale and a container with a spout are useful, as it's easier to measure ball quantities by weight rather than counting each ball.

8 On Choosing the Balls

Use only precision-machined, evenly polished, high-quality balls from known manufacturers (e.g., Gamo, Umarex, SwissArmy). Smaller balls yield better sound quality even at lower volumes because they require less energy to move.

1. **Ball size**
   - **Small balls (1–3 mm):**
     Provide high density and fill the container evenly. Very good for damping subtle, high-frequency vibrations.
   - **Medium balls (4–8 mm):**
     A good compromise between small and large balls. Provide effective damping over a broad frequency range.
   - **Large balls (over 8 mm):**
     Better at damping low-frequency vibrations and impacts.
2. **Ball material**
   - **Steel balls:** heavy and wear-resistant, ideal for hi-fi use.
   - **Stainless steel balls:** corrosion-resistant.

- **Lead balls:** extremely heavy but not environmentally friendly.
- **Ceramic balls:** lighter, lower damping capacity.
- **Tungsten balls:** most expensive, but best damping performance.

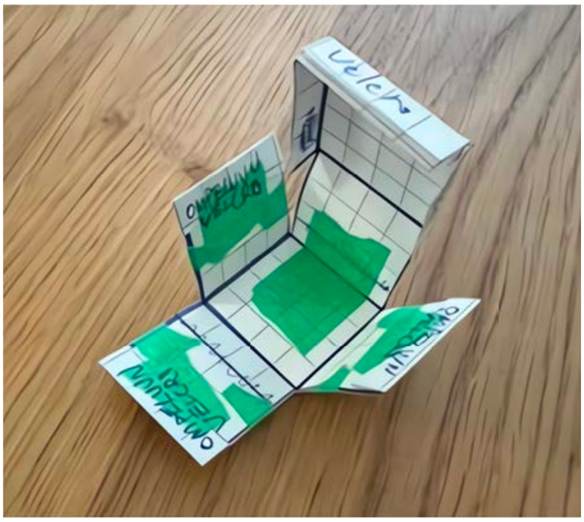
9 Making the Dampers

Using the **Hi-Fi Damping Calculator mobile app**, you can design a ball-damping solution suitable for your audio device. The app provides suggestions, for instance:

- Based on the weight of the device to be damped
- Number of balls (and diameter)
- Dimensions of each container

You can then manufacture the containers, have them made by a tailor, or purchase suitably sized cotton or thin, soft leather bags, cylinders, cubes, or boxes. You can also buy cardboard boxes of the right size if leveling is critical, e.g., with a turntable.

(a) Finished leather bag and testing



(b) Custom-designed box

Kuva 5: Measuring

(a) Supplies

(b) Steel balls

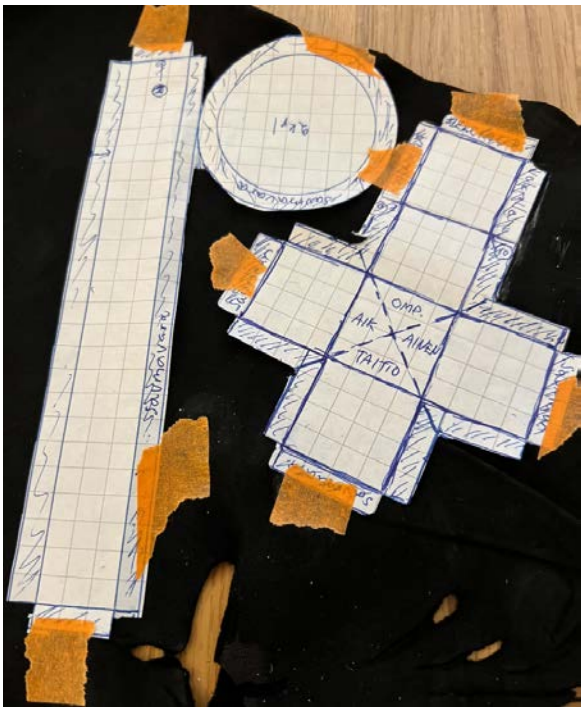
Kuva 6: Materials

(a) Cylindrical cardboard container, filled with balls

(b) Wooden rectangular box, filled with balls

Kuva 7: Various containers

(a) Plastic container, filled with balls



(b) Patterns laid out for cutting

Kuva 8: Various containers and patterns

(a) Leather coin purse

(b) Leather "sugar bag"

Kuva 9: Leather bags

(a) Wooden boxes (b) Wooden boxes

Kuva 10: Wooden containers of different shapes

(a) Black cardboard boxes (b) Light-colored cardboard boxes

Kuva 11: Cardboard boxes that can be found online using keywords “gift box,” “jewelry box,” or “cardboard box”

In Figure 12a, there are two cylindrical leather pieces reversed and stacked. One, the “lid,” is 2 mm larger in diameter than the bottom. The right amount of balls goes into the bottom piece, both are cut to the correct and identical length, and the lid slides over the bottom piece, forming double walls and creating a so-called cylinder-button foot. It’s easy to make, easy to level, and can be as stylish as you like, provided the leather is about 1 mm thick and soft.

(a) Leather container filled with balls

(b) Leather container

Kuva 12: Leather containers

9.1 Manufacturing a Cylindrical Leather Foot

Below are instructions for making a cylindrical leather foot:

1. Figure 13a: Cut out two cylindrical pieces based on the internal dimensions provided by the mobile app. The one that becomes the lid must be 2 mm wider in diameter than the one for the bottom.

2. Figure 13b: Sew the cylinders with their right sides facing inward.

3. Figure 14a: Turn both cylinders right-side out, so the outer surface is facing outward.

4. Figure 14b: Take the smaller cylinder, i.e., the bottom.

5. Figure 15a: Fill the bottom cylinder with the number of balls recommended by the mobile app; if needed, trim with scissors to match the balls' height.

6. Figure 15b: If needed, trim the lid cylinder with scissors and slide it over the bottom cylinder, forming:

7. Figure 16a: A leather ball reservoir in the shape of a foot for damping.

You can just as well use cotton canvas fabric. If you use leather as in the photos, use approx. 1 mm thick soft leather.

(a) Step 1

(b) Step 2

Kuva 13: Manufacturing a cylindrical leather foot. The prototype in the photo was assembled with a stapler, but in the final version it is recommended to use a regular sewing machine with a leather needle or hand sewing.

(a) Step 3

(b) Step 4

Kuva 14: Manufacturing a cylindrical leather foot

(a) Step 5

(b) Step 6

Kuva 15: Manufacturing a cylindrical leather foot

(a) Step 7

Kuva 16: Manufacturing a cylindrical leather foot

10 Installing the Dampers and Use Cases

Always isolate the main sources of vibration first: speakers, subwoofers, and Helmholtz (or slot) resonators.

- **Floor situation:**
  - A floating parquet floor can vibrate, so isolation is important.
  - If the floor is solid, it may be less significant, and a solid coupling to the floor can sometimes be better.
- **Speaker stability vs. isolation:**
  - Dampers under the speaker affect its height.
  - You need to balance stability and isolation.
- **Internal microvibration in audio devices:**
  - Install (3–6) dampers directly against the device's bottom chassis.
  - Distribute the device's weight evenly on each damper.
- **Combinations of multiple materials:**
  - You can use different filling materials in different bags, achieving damping for various frequency ranges.
- **Cable damping:**
  - For cables, ball dampers usually aren't appropriate because the cable mass is small.

> ”The signal used by your system, be it digital or analog, through tube or solid state, is always alternating current...”

(Source: https://www.cardas.com/deep-dive)

10.1 Lightweight Devices

Below the device, you should place ball-reservoir dampers with the correct number of balls (calculated by the app), without any other damping (like the device’s own original feet). An exception might be speakers, which often have built-in feet that can help with stability.

However, on top of both lightweight and heavier devices, you should almost always add additional granular material to broaden the range of vibration control, since more than the device’s own main resonance frequency is at play (coming from structures, air, cables, and inside the device).

On top of devices, especially lightweight audio electronics, it’s worthwhile to place bags, boxes, or containers containing various granular materials, such as different kinds of steel balls, sand, technical rubber granules, or powder—almost anything. You don’t need to mix them all; you can have separate containers for separate materials.

- Separate containers can also distribute mass differently, which might benefit structural balance.
- **Collision and friction dynamics**
  - When particles of different sizes or materials are **in the same container**, they can also collide among themselves. This produces a complex (often very effective) energy-dissipating damping phenomenon, because collisions between particles increase entropy and disperse energy in multiple directions.
  - If different kinds of particles are **in separate containers**, they don’t directly affect each other by collision, and each container acts as its own damping channel. However, separate containers can be designed to complement each other.
- **Mixing, packing, and segregation**
  - Particles differing in size or weight can **segregate** when moved in a container, with heavier or larger ones settling at the bottom and lighter ones near the top. This can help or hinder damping depending on the situation. Sometimes the right segregation can enhance friction, but sometimes it means some particles no longer move freely.
  - **Separate containers** can prevent unwanted segregation or control it better (e.g., each container only has one particular particle size).
- **Frequency range coverage**
  - The idea is that each material/particle type is “optimized” for damping certain kinds or ranges of vibration (e.g., heavy steel balls handle larger amplitudes, while lighter

or more frictional granules respond more readily to minor movement).

– **Mixed in the same container**, their combined effect may cover a wide range but is more unpredictable.

– **In different containers**, you can specify geometric (size, shape) and material (density, hardness) parameters for each container, "tuning" them to a particular vibration range. This achieves multi-frequency damping in a controlled way.

Placing an assortment of dampers on top also adds overall weight to the device, giving it more stability.

When using added-weight sand, desert sand is recommended, as it is naturally rounded and uniform. This is excellent for adding weight to lightweight devices, while also providing broad-range vibration damping.

Kuva 17: Added-weight desert sand in a black leather case

11 Testing the Effect

You can confirm the change audibly or, for example, with the Vibration meter mobile app.

Testing before and after damping:

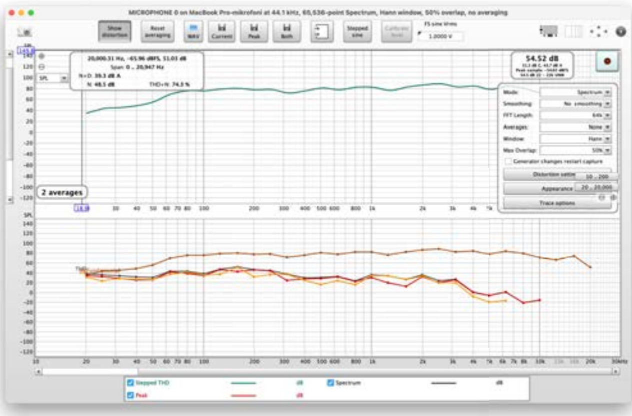
- Compare measurements using the same test track and volume level.
- Measure from the top of the device, from the floor, from a rack, etc.

11.1 REW Software

The free **REW** software (Room EQ Wizard) allows you to compare "before vs. after."

- THD (total harmonic distortion) and THD+N measurement.

- Lower distortion indicates effective isolation and damping.
- REW does not tell how “pleasant” the sound is—this is subjective.



Kuva 18: Measurement using REW’s Real-Time Analyzer (RTA)

11.1.1 Measurement Info: SNR (Signal-to-Noise Ratio)

SNR describes the signal strength relative to background noise. Dampers can reduce mechanical vibration, which can reduce noise, improving SNR.

11.1.2 Measurement Info: SDR (Signal-to-Distortion Ratio)

SDR reflects the signal strength relative to harmonic distortion. Dampers may decrease harmonic distortion caused by resonance and vibration.

11.1.3 Clarity: C80 (Music Clarity Index)

C80 describes musical clarity by examining how much of the sound energy arrives in the first 80 milliseconds relative to later arriving energy.

Dampers can improve the C80 score by reducing reflections and resonances caused by vibration.

11.2 Interpreting Vibration Meter Results

- **Peak (huippuarvo):** Shows the maximum intensity of the vibration.
- **RMS (Root Mean Square):** Describes the average level of vibration over time.

- **Frequencies (Taajuudet):** How do various frequencies (e.g., bass range) affect vibration?

Do the peak values go down? Does the RMS decrease? Changes in the bass range (20–200 Hz) are often significant if the damping works effectively.

12 User Experiences

"Now that I've been listening to music for several days across different genres (jazz, bluegrass, indie, blues), on thoroughly familiar albums, I've noticed the following:"

- Increased detail / articulation.
- Greater presence.
- Music plays more cleanly, without distortion, sometimes leading me to turn the volume up more.
- The sound has more warmth and detail thanks to more resonance-free playback.
- The difference is strikingly big, and I couldn't do without these dampers anymore!
- My enthusiasm for listening to music has reached new levels, as even well-known recordings now reveal new "aha!" moments.