

Non-Contact Control of Drumhead Resonance Decay by a Proximity Acoustical Resistor

A Technical Disclosure with Measured Demonstrations

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Defensive publication. This document is released publicly as a *defensive publication* (prior art). The methods described — conceived by the author in the late 1970s, reduced to a detailed design and measured, but never filed as a patent and never previously disclosed publicly — are dedicated to the public domain so that anyone may freely practice them and no party may obtain patents that read on the disclosed subject matter. This is an intentionally enabling disclosure: it includes the governing principle, a family of embodiments with the inventor’s original drawings, measured demonstrations, and the complete analysis code. The authoritative date of public disclosure is the timestamp of the archived record in which this document appears; see Section 7.

Abstract

A method is disclosed for shortening and tuning the decay time of a drumhead’s resonant modes — including *selectively* shortening the overtones — using an acoustically resistive element held in close proximity to, but *not touching*, the drumhead. A porous or perforated material (open-cell foam, cloth, fiber, or perforated metal or plastic) is positioned within a distance small compared with the wavelength of the mode of interest. The oscillating near-field air motion driven by the vibrating membrane is forced through the resistive material, where viscous and thermal losses convert modal energy to heat, raising the modal damping and shortening the decay time. Because the near field of a membrane mode has a spatial extent and structure set by its wavelength, the geometry and placement of the resistor — ring inside diameter, gap distance, coverage, and orientation — select which modes are damped, allowing the fundamental, the overtones, or both to be targeted, either at a fixed setting or continuously adjustable. Unlike contact mufflers, gels, rings, and internal dampers, nothing touches or loads the vibrating surface, so the head’s strike response and feel are preserved. The disclosure gives the physical principle, a family of embodiments (ring, disk, cylinder, adjustable aperture, pivoting central “flue,” near-head pattern, and perimeter blocks) with the inventor’s original drawings, and measured demonstrations on struck toms (spectrograms, energy-decay curves, and RT_{60} decay times) that confirm strong, tunable, contact-free decay control that meets or exceeds a commercial contact muffler. The purpose of the disclosure is to place these methods and their variants permanently in the public domain.

Keywords: drumhead; membrane damping; overtone control; acoustic resistance; porous absorber; decay time; RT_{60} ; sustain control; non-contact muffling; percussion; defensive publication; prior art.

1 Introduction and motivation

Players of drums and tuned percussion routinely need to control the *sustain* and *overtone content* of a drumhead: a tom or snare that rings too long or sings unwanted high partials must be tamed

for the room, the microphone, or the musical context. The established ways of doing this all share one property: they *touch the vibrating head*. Adhesive gel pads, felt or foam strips, “O-ring” and control-ring dampers laid on the head, internal mufflers pressed against the underside, and external arm dampers all add mass and mechanical loading directly to the membrane. That contact does shorten the decay, but it also alters the very thing the drummer feels and hears: the attack, the rebound, the pitch, and the touch response of the head change together with the sustain, and the effect is difficult to adjust in a graded, repeatable way.

This disclosure describes a different approach, conceived by the author in the late 1970s and subsequently reduced to a detailed set of embodiments and supported by acoustic measurements. Instead of loading the membrane, an acoustically *resistive* element is held in the air *near* the head but not touching it. The near-field air motion that the vibrating head necessarily drives is made to pass through the resistive material, which dissipates the modal energy. Because nothing contacts the head, the strike response and feel are preserved; and because the coupling is through the mode’s near field, the *geometry* of the element can be used to choose which modes are damped — in particular, to shorten the long-ringing overtones while leaving the fundamental comparatively intact, or to do the reverse, or both. The method was never patented and never publicly disclosed; it is published here as prior art.

2 Relationship to prior work

Drum damping is a crowded field, but the relevant prior art is almost entirely *contact* based. Representative categories include: rings or discs of film or foam laid on the head (control rings); adhesive gel or moongel pads; felt or foam “tone control” mufflers mounted inside the shell and pressed against the underside of the head by a lever or spring; external adjustable arms that bring a felt pad down onto the head; and pillows or foam placed inside bass drums in contact with the head. The author compiled an extensive collection of such patents and products during the development of this work (including, e.g., U.S. Patent 4,254,685 and numerous later muffling and impact-pad patents), and in every case the damping element makes mechanical contact with, and adds mass or a compliant load to, the vibrating membrane.

The distinguishing element disclosed here is that the damping element is *non-contacting*: it is held in acoustically close proximity to the head and removes energy through the air, by acoustic resistance, rather than by touching or loading the membrane. The physics of porous acoustic absorbers and acoustic resistance is classical [3, 4], and the modal acoustics of drum membranes is well described [1, 2]; what is disclosed here is the application of a proximity acoustic resistor to selectively and adjustably control the decay of drumhead modes without contact, together with the specific family of embodiments and mounting geometries of Section 4. No proprietary claim is made to the underlying acoustics, which is classical.

3 Physical principle

3.1 Near-field coupling and acoustic resistance

A drumhead vibrating in one of its membrane modes moves the air immediately adjacent to it. Within roughly one wavelength of the surface, most of this motion is a reactive, largely incompressible “sloshing” of air back and forth (the evanescent near field) rather than radiated sound; it carries oscillating kinetic energy that is normally returned to the mode each cycle. If an acoustically resistive layer — a porous or perforated material with a real flow resistance — is placed in

this near field, the oscillating air is forced through its narrow channels, and viscous and thermal losses convert part of that kinetic energy irreversibly to heat. The layer presents a specific acoustic resistance

$$R_a \approx \sigma t, \quad (1)$$

where σ is the flow resistivity of the material and t its thickness (for a thin layer, below the regime where reactance dominates). Introducing R_a into the near field of a mode adds a dissipative term to that mode's dynamics.

3.2 Decay time and damping

A struck mode of natural frequency $\omega_0 = 2\pi f_0$ and damping ratio ζ rings down with an amplitude envelope $\propto e^{-\zeta\omega_0 t}$. Its 60 dB decay time is

$$\text{RT}_{60} = \frac{3 \ln 10}{\zeta \omega_0} = \frac{60 \text{ dB}}{(\text{decay slope, dB/s})}, \quad (2)$$

the right-hand operational form (sixty decibels divided by the measured decay slope) being the one used for the data below. Adding acoustic resistance in the mode's near field increases ζ and therefore shortens RT_{60} . The amount of shortening grows with how strongly the resistor couples to that particular mode.

3.3 Mode selectivity through geometry

The key to selective control is that different modes present different near fields. A higher-order mode (an overtone) has a shorter wavelength and a finer spatial pattern of antinodes; its reactive near field is correspondingly *thinner* and more sharply localized against the head. A resistor placed at a small gap distance d from the head therefore couples strongly to the thin, high-wavenumber near field of the overtones, damping them heavily, while a resistor withdrawn to larger d reaches only the broader near field of the low-order fundamental. Likewise, the lateral coverage of the element selects modes by their antinodal pattern: a ring with a given inside diameter (ID) overlaps the fundamental's central antinode differently than it overlaps the ring-shaped antinodes of the overtones. In qualitative summary, and consistent with the measurements below,

smaller gap $d \Rightarrow$ shorter overtone decay; smaller ring ID $\Rightarrow$ shorter fundamental decay.

A special case is a resistive disc placed on a pivot at the *center of the shell*, far from the head: it is too distant to reach the overtones' near field and instead acts as an adjustable “flue” throttling the bulk air exchange of the enclosed cavity, controlling mainly the fundamental. For two-headed drums the shell and heads form a coupled (Helmholtz-like) cavity resonator; resistance placed within the cavity or near the resonant head damps the coupled system. These distinctions are what allow one design family to target the fundamental, the overtones, or both.

4 The device and its embodiments

The acoustic resistor is a ring, disc, cylinder, volume, or pattern of perforated, porous, or open-cell material — foam, cloth, fiber, perforated metal, or plastic — held in acoustically close proximity to the drumhead by a fixed or adjustable frame, without touching the head except, optionally, at the extreme edge (shell or rim) for mounting. It may be mounted on the shell, on the rim, or on the head near the rim, on either the inner (preferred) or outer surface, and on the batter head, the

resonant head, or both. “Acoustically close” means a gap small compared with the wavelength of the mode to be damped. The principal embodiments, shown in the author’s original drawings in Appendix A, are:

- **Ring** (Fig. 4) — a ring of resistor material of a chosen inside diameter held at gap d ; ID and d set the balance of fundamental versus overtone damping.
- **Disc or cylinder** — a solid resistive shape in close proximity; damps both fundamental and overtones.
- **Adjustable aperture** (Fig. 5) — an iris-like element whose effective ID is varied to tune the fundamental/overtone balance on the fly.
- **Pivoting central “flue”** (Fig. 6) — a resistive disc on a central pivot in the shell, adjusted by a control knob; from open (little effect) to closed (shortest fundamental), it controls mainly the fundamental.
- **Near-head pattern** (Fig. 7) — a pattern of resistor material with its long dimension perpendicular to and acoustically close to the head; targets overtones with little effect on the fundamental.
- **Perimeter blocks** (Fig. 8) — small blocks of open-cell foam attached to the shell at a small gap d (e.g. ~ 5 mm) from the head; shorten the overtones while affecting the fundamental only slightly.

5 Experimental demonstration

5.1 Method

A tom (one-headed, and a two-headed 13-inch drum) was struck and recorded under a series of conditions: the naked head; a commercial contact muffler (Remo Muff’ls); and the acoustical resistor in several configurations (full-coverage resistor, resistor rings of two inside diameters, a small perimeter gap, and an adjustable element set to “small,” “medium,” and “full”). Decay was characterized three ways: short-time spectrograms; the broadband energy-decay envelope; and the 60 dB decay time RT_{60} of individual partials, obtained by fitting the decay slope in decibels per second per Eq. (2). The complete analysis code is given in Appendix B; it uses only `numpy`, `scipy`, and `matplotlib`, and reproduces every figure and number below from the recordings.

5.2 Results

Spectrograms. Figure 1 shows the qualitative effect. On the naked head, overtone bands at roughly 200, 400, 600, and 800 Hz ring for one to two seconds; the commercial muffler and every acoustical-resistor configuration collapse these overtones quickly. The two ring configurations show the geometry dependence directly.

Decay times. Figure 2 quantifies it. Panel (A) shows the broadband energy envelope: the naked head reaches -20 dB only after several tenths of a second and rings well beyond a second, whereas the acoustical resistor brings the decay down to, or below, that of the commercial contact muffler. Panel (B) reproduces the author’s own RT_{60} measurements on the 13-inch drum for the fundamental (110 Hz) and the first overtone (220 Hz). The single most striking number is that on the naked head the *overtone* rings longest of all, $RT_{60} \approx 2.3$ s, far longer than the fundamental’s

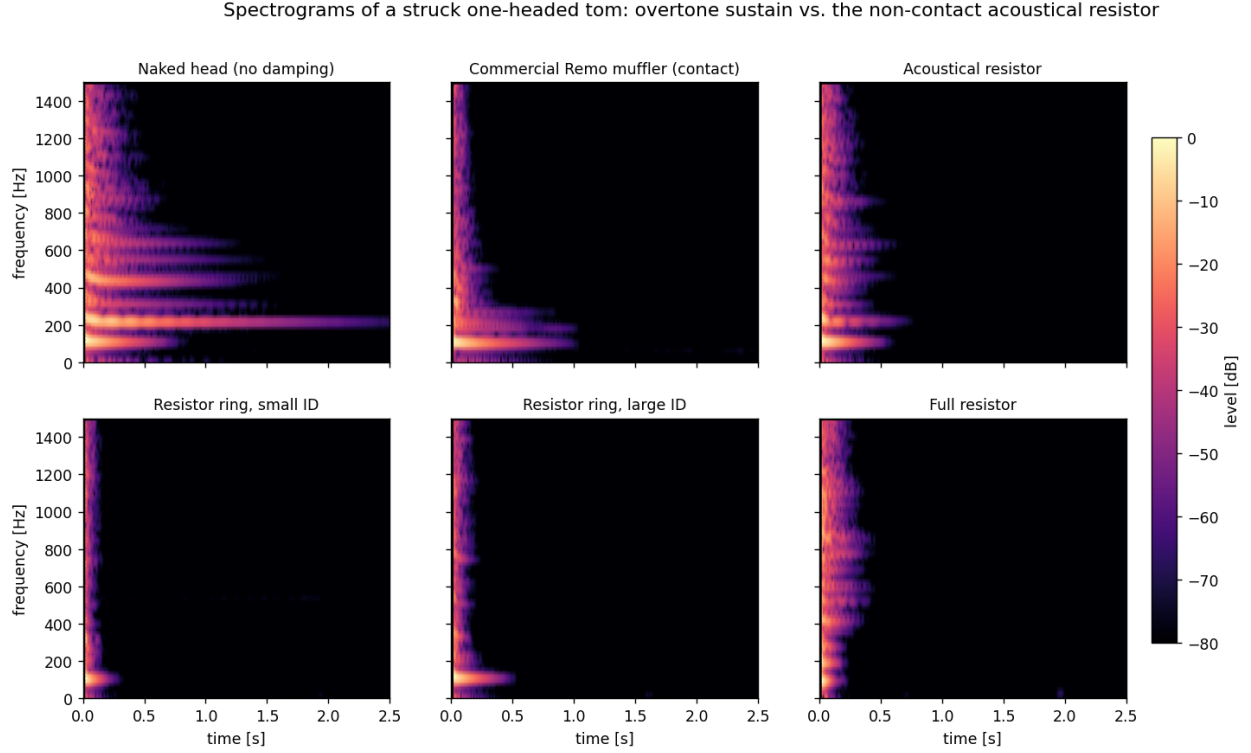


Figure 1: Spectrograms of a struck one-headed tom under six conditions (shared level scale). The naked head sustains strong overtone bands for seconds; the non-contact acoustical resistor collapses them, comparably to a commercial *contact* muffler, with the ring inside diameter and coverage controlling the result.

≈ 1.0 s; the non-contact resistor reduces that overtone to 0.2–0.6 s depending on setting. Table 1 lists the values.

Tunability. Figure 3 shows the adjustable embodiment set to three positions. A single non-contact device produces a smooth family of decay curves spanning from near the naked head down to, and beyond, the commercial contact muffler — graded, repeatable control that contact dampers achieve only awkwardly.

5.3 Interpretation and honest limits

The recordings establish, unambiguously, that a material held *near but not touching* the head strongly shortens the decay of its modes, that the effect is continuously adjustable, and that it can meet or exceed a commercial contact muffler — all without loading the membrane. They also show the expected geometry dependence (ring ID, gap, coverage). Two honest caveats: first, in the particular configurations recorded, the resistor shortens *both* the fundamental and the overtones, with the long-ringing overtones reduced at least as much as the fundamental; a claim of leaving the fundamental wholly untouched is design- and setting-dependent and is not asserted from these specific recordings. Second, the measurements are single-drum demonstrations, not a controlled parametric study across drum sizes, materials, and gaps; the disclosed principle and embodiments are intended to enable such optimization rather than to report it exhaustively.

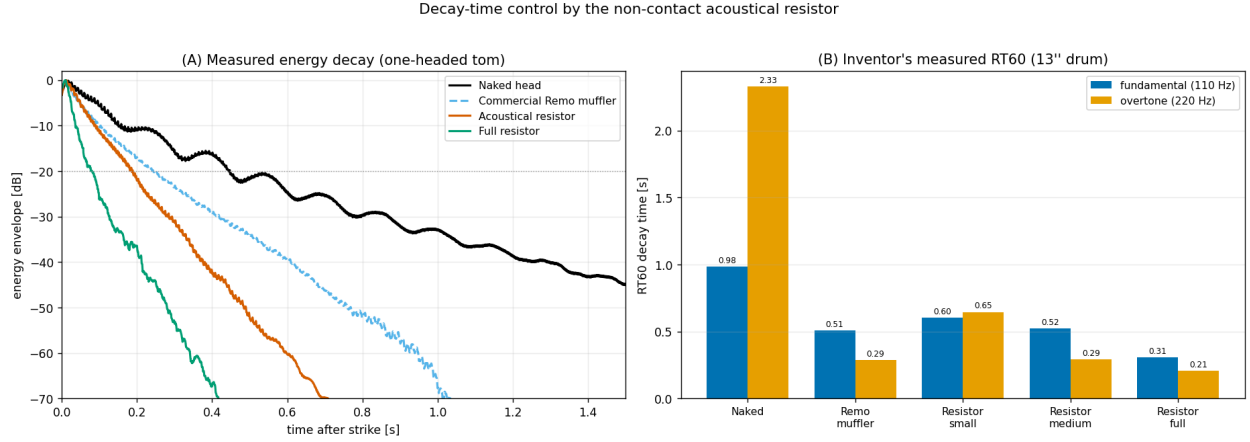


Figure 2: (A) Measured broadband energy decay of a struck one-headed tom: the acoustical resistor decays as fast as or faster than the commercial contact muffler. (B) The inventor’s measured RT_{60} decay times on a 13-inch drum for the 110 Hz fundamental and the 220 Hz overtone. The naked overtone rings longest (≈ 2.3 s) and is strongly suppressed by the non-contact device.

Table 1: Inventor’s measured RT_{60} decay times (seconds), 13-inch drum, from the decay-slope method of Eq. (2).

Condition	Fundamental, 110 Hz	Overtone, 220 Hz
Naked head	0.98	2.33
Commercial contact muffler (Remo)	0.51	0.29
Acoustical resistor — small	0.60	0.65
Acoustical resistor — medium	0.52	0.29
Acoustical resistor — full	0.31	0.21

6 Enumerated variants

For breadth of disclosure the following non-exhaustive variants, and any workable combination of them, are expressly included.

1. Resistive material of any perforated, porous, or open-cell type: foam, cloth, felt, fiber, woven or sintered metal, or perforated/louvered plastic or metal.
2. Element geometry: ring, disc, cylinder, tube, volume, aperture/iris, louver, pivoting flue, or a discrete or continuous near-head pattern.
3. Fixed or continuously adjustable gap distance d , inside diameter, or coverage, by manual, mechanical, or motorized means.
4. Mounting on the shell, the rim, or the head near the rim; on the inner (preferred) or outer surface; on the batter head, the resonant head, or both.
5. Targeting of mainly the fundamental, mainly the overtones, or both, by choice of the above.
6. Combination with cavity/Helmholtz tuning in single- or double-headed drums, including resistance placed within the enclosed cavity.

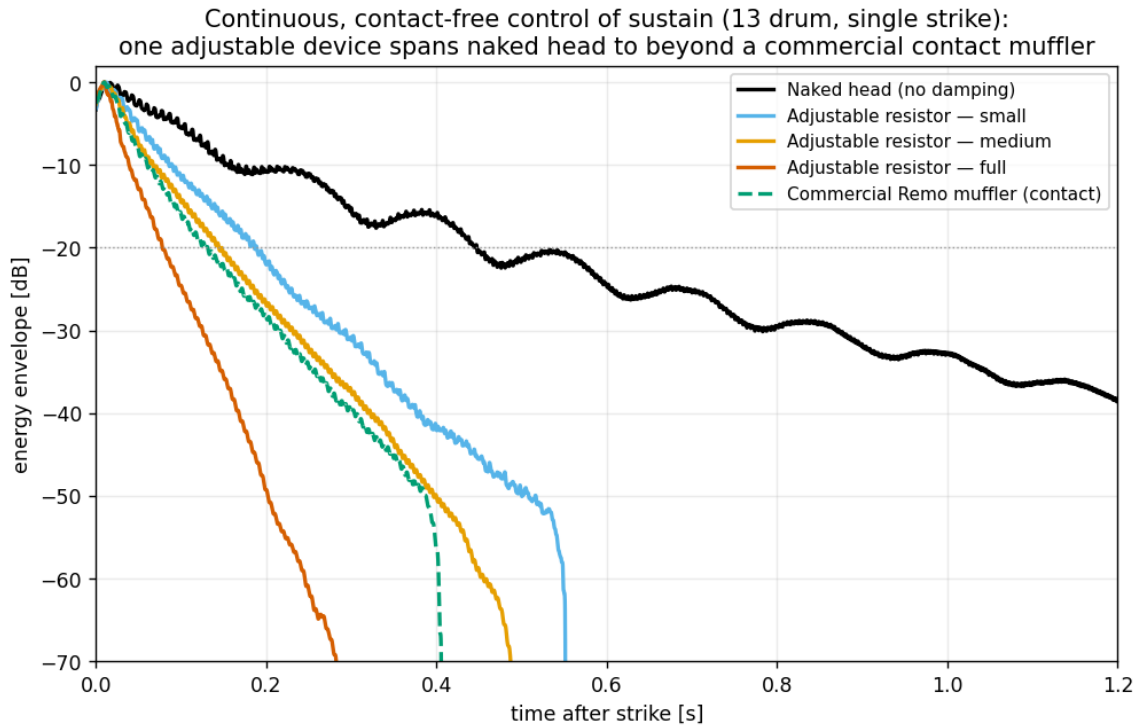


Figure 3: Continuous, contact-free control of sustain (13-inch drum, single strike): one adjustable acoustical resistor spans from the naked head to beyond a commercial contact muffler as it is opened from “small” to “full.”

7. Application to any struck membranophone — toms, snare, bass drum, timpani, congas, and the like — and to other membrane or plate resonators where selective, non-contact decay control is desired.
8. Integration with sensing or with a remote/automated control of the adjustable element.

7 Publication status and establishing priority

This device was conceived by the author in the late 1970s, developed into the detailed embodiments and measurements presented here, but *never filed as a patent and never previously disclosed publicly*. It is published now as a defensive publication: an enabling, dated, public description whose purpose is to place the methods and their variants in the public domain, so that anyone may use them and no party may later obtain a patent that reads on the disclosed subject matter. The authoritative date of public disclosure is the timestamp of the archived record in which this document appears (for example, a DOI-bearing repository deposit), not any date printed on this page. For the disclosure to function as prior art it must be public, dated, and discoverable; to that end it is deposited in venues that provide an authoritative timestamp and indexing that patent examiners search. A defensive publication is effective only to the extent it is *enabling*: the principle of Section 3, the embodiments and original drawings of Section 4 and Appendix A, the measured demonstrations of Section 5, and the complete analysis code of Appendix B are included to meet that bar for the disclosed methods and their enumerated variants. Publication is deliberate and, by design, places the methods in the public domain; it is generally irreversible with respect to the author’s own

patent rights, which the author knowingly forgoes.

This draft was prepared with computational assistance for the acoustic analysis and typesetting. The invention, drawings, and measurements are the author's; nothing here is legal advice.

References

- [1] T. D. Rossing. *Science of Percussion Instruments*. World Scientific, 2000.
- [2] N. H. Fletcher and T. D. Rossing. *The Physics of Musical Instruments*, 2nd ed. Springer, 1998 (membranes and drums).
- [3] P. M. Morse and K. U. Ingard. *Theoretical Acoustics*. McGraw-Hill, 1968 (acoustic impedance and dissipation).
- [4] U. Ingard. *Noise Reduction Analysis*. Jones & Bartlett, 2010 (flow resistance and porous acoustic resistance).
- [5] U.S. Patent 4,254,685 and related drum-muffling patents, collected by the author as prior-art context (contact-type dampers).

A Inventor's original drawings

The following are the author's original design drawings for the principal embodiments (headers cropped). They date from the development of the device and are reproduced here as part of the enabling disclosure.

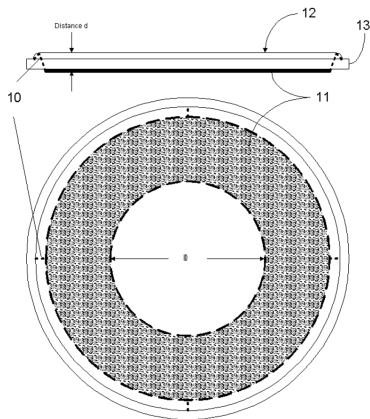


Figure 1

Figure 4: Ring embodiment: a ring of resistor material of inside diameter ID held at gap d from the head.

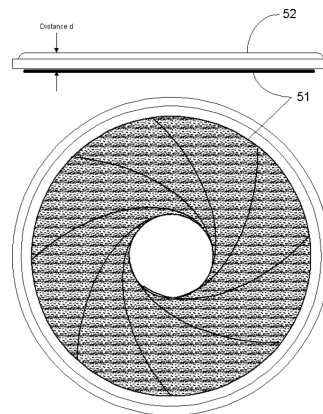


Figure 5

Figure 5: Adjustable-aperture embodiment: the effective inside diameter is varied to tune the fundamental/overtone balance.

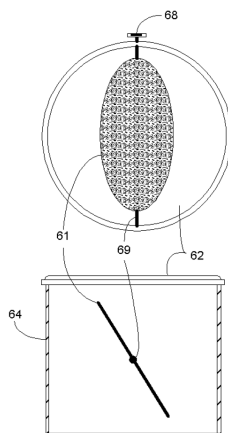


Figure 6

Figure 6: Pivoting central "flue": a resistive disc on a central pivot, adjusted by a knob, controlling mainly the fundamental.

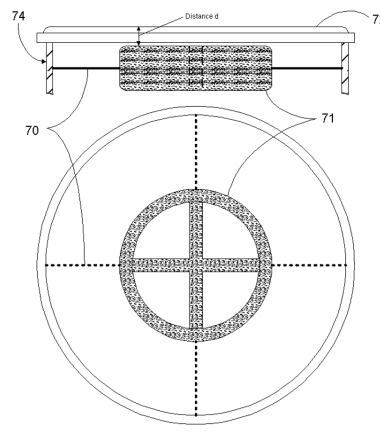


Figure 7

Figure 7: Near-head pattern: resistor material acoustically close to the head, targeting overtones.

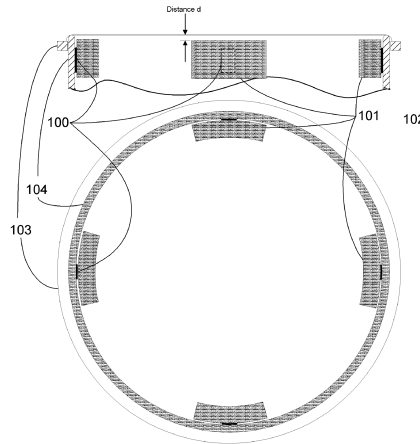


Figure 10

Figure 8: Perimeter-block embodiment: small open-cell foam blocks attached to the shell at a small gap d from the head, shortening the overtones while affecting the fundamental only slightly.

B Analysis code (complete)

The following reproduces the spectrograms, decay curves, and figures from the recordings using only `numpy`, `scipy`, and `matplotlib`.

```

1  """
2  Acoustical-resistor drumhead damping: analysis of the demonstration recordings.
3
4  Reproduces the figures used in the technical disclosure from the WAV/MP3
5  recordings (decoded to wav/*.wav). Uses only numpy + scipy + matplotlib.
6
7  Author: analysis accompanying Calvin D. Rose's disclosure. SPDX: Apache-2.0.
8  """
9  import numpy as np, scipy.io.wavfile as wav, scipy.signal as sig
10 import matplotlib; matplotlib.use('Agg'); import matplotlib.pyplot as plt
11
12 # Okabe-Ito colorblind-safe palette
13 OK = dict(black='#000000', orange='#E69F00', sky='#56B4E9', green='#009E73',
14           yellow='#F0E442', blue='#0072B2', verm='#D55E00', purple='#CC79A7')
15
16 def load(k, thresh=0.2):
17     sr, x = wav.read(f'wav/{k}.wav'); x = x.astype(float)
18     if x.ndim > 1: x = x.mean(1)
19     x /= (np.abs(x).max() + 1e-9)
20     i0 = np.argmax(np.abs(x) > thresh * np.abs(x).max())
21     return sr, x[i0:]
22
23 def env_db(x, sr, hop_ms=20):
24     fl = max(1, int(hop_ms/1000*sr))
25     e = np.sqrt(np.convolve(x**2, np.ones(fl)/fl, 'same'))
26     return 20*np.log10(e/(e.max()+1e-12)+1e-12)
27
28 def band(x, sr, lo, hi):
29     sos = sig.butter(4, [lo/(sr/2), min(hi, sr/2*0.99)/(sr/2)], 'band', output='sos')
30     return sig.sosfiltfilt(sos, x)
31
32 # ----- Figure 1
33 def fig_spectrograms():
34     conds = [('oh_naked', 'Naked head (no damping)'),
35             ('oh_remo', 'Commercial Remo muffler (contact)'),
36             ('oh_resistor', 'Acoustical resistor'),

```

```

37         ('oh_ring', 'Resistor ring, small ID'),
38         ('oh_largering', 'Resistor ring, large ID'),
39         ('oh_full', 'Full resistor')]
40 fig, axs = plt.subplots(2, 3, figsize=(15, 7.4), sharex=True, sharey=True)
41 for ax, (k, title) in zip(axs.ravel(), conds):
42     sr, x = load(k)
43     f, t, S = sig.spectrogram(x, sr, nperseg=2048, noverlap=1536, window='hann')
44     Sdb = 10*np.log10(S/S.max()+1e-12)
45     m = f <= 1500
46     ax.set_facecolor('#000004')
47     pc = ax.pcolormesh(t, f[m], Sdb[m], vmin=-80, vmax=0, cmap='magma', shading='gouraud')
48     ax.set_title(title, fontsize=10); ax.set_ylim(0, 1500); ax.set_xlim(0, 2.5)
49 for ax in axs[:, 0]: ax.set_ylabel('frequency [Hz]')
50 for ax in axs[1, :]: ax.set_xlabel('time [s]')
51 fig.suptitle('Spectrograms of a struck one-headed tom: overtone sustain vs. the non-contact acoustical
52             resistor',
53             fontsize=12.5)
54 cb = fig.colorbar(pc, ax=axs, shrink=0.82, pad=0.02); cb.set_label('level [dB]')
55 fig.savefig('fig1_spectrograms.png', dpi=125, bbox_inches='tight')
56 print('saved fig1_spectrograms.png')
57 # ----- Figure 2
58 def fig_decay_and_rt60():
59     fig, (axA, axB) = plt.subplots(1, 2, figsize=(15, 5.4))
60
61     # (A) measured broadband energy-decay curves (One Head set)
62     curves = [('oh_naked', 'Naked head', OK['black'], '-'),
63              ('oh_remo', 'Commercial Remo muffler', OK['sky'], '--'),
64              ('oh_resistor', 'Acoustical resistor', OK['verm'], '-'),
65              ('oh_full', 'Full resistor', OK['green'], '-')]
66     for k, lab, c, ls in curves:
67         sr, x = load(k)
68         edb = env_db(x, sr)
69         t = np.arange(len(edb))/sr
70         axA.plot(t, edb, color=c, ls=ls, lw=1.8, label=lab)
71     axA.axhline(-20, color='0.6', lw=0.8, ls=':')
72     axA.set_xlim(0, 1.5); axA.set_ylim(-70, 2)
73     axA.set_xlabel('time after strike [s]'); axA.set_ylabel('energy envelope [dB]')
74     axA.set_title('(A) Measured energy decay (one-headed tom)')
75     axA.legend(fontsize=9); axA.grid(alpha=0.25)
76
77     # (B) inventor's measured RT60 (13-inch drum): fundamental 110 Hz vs overtone 220 Hz
78     labels = ['Naked', 'Remo\nmuffler', 'Resistor\nsmall', 'Resistor\nmedium', 'Resistor\nfull']
79     rt_f = [0.985, 0.507, 0.604, 0.523, 0.306] # 110 Hz fundamental
80     rt_o = [2.328, 0.288, 0.646, 0.294, 0.209] # 220 Hz overtone
81     x = np.arange(len(labels)); w = 0.38
82     axB.bar(x-w/2, rt_f, w, label='fundamental (110 Hz)', color=OK['blue'])
83     axB.bar(x+w/2, rt_o, w, label='overtone (220 Hz)', color=OK['orange'])
84     axB.set_xticks(x); axB.set_xticklabels(labels, fontsize=9)
85     axB.set_ylabel('RT60 decay time [s]')
86     axB.set_title("(B) Inventor's measured RT60 (13'' drum)")
87     axB.legend(fontsize=9); axB.grid(alpha=0.25, axis='y')
88     for xi, (a, b) in enumerate(zip(rt_f, rt_o)):
89         axB.text(xi-w/2, a+0.03, f'{a:.2f}', ha='center', fontsize=7)
90         axB.text(xi+w/2, b+0.03, f'{b:.2f}', ha='center', fontsize=7)
91     fig.suptitle('Decay-time control by the non-contact acoustical resistor', fontsize=12.5)
92     fig.tight_layout(rect=[0,0,1,0.96])
93     fig.savefig('fig2_decay_rt60.png', dpi=125, bbox_inches='tight')
94     print('saved fig2_decay_rt60.png')
95
96 # ----- Figure 3
97 def fig_tunability():
98     """The adjustable embodiment gives continuous, contact-free control of sustain:
99     the same device set to small / medium / full produces a monotonic family of
100     decay curves between the naked head and the commercial contact muffler."""
101     fig, ax = plt.subplots(figsize=(9.2, 5.4))
102     curves = [('naked', 'Naked head (no damping)', OK['black'], '-'),
103              ('cdr_small', 'Adjustable resistor -- small', OK['sky'], '-'),

```

```

104         ('cdr_medium', 'Adjustable resistor -- medium', OK['orange'], '--'),
105         ('cdr_full', 'Adjustable resistor -- full', OK['verm'], '--'),
106         ('remo', 'Commercial Remo muffler (contact)', OK['green'], '--')]
107 for k, lab, c, ls in curves:
108     sr, x = load(k)
109     edb = env_db(x, sr); t = np.arange(len(edb))/sr
110     ax.plot(t, edb, color=c, ls=ls, lw=1.9, label=lab)
111     ax.axhline(-20, color='0.6', lw=0.8, ls=':')
112     ax.set_xlim(0, 1.2); ax.set_ylim(-70, 2)
113     ax.set_xlabel('time after strike [s]'); ax.set_ylabel('energy envelope [dB]')
114     ax.set_title('Continuous, contact-free control of sustain (13" drum, single strike):\n'
115                 'one adjustable device spans naked head to beyond a commercial contact muffler')
116     ax.legend(fontsize=8.8, loc='upper right'); ax.grid(alpha=0.25)
117     fig.savefig('fig3_tunability.png', dpi=125, bbox_inches='tight')
118     print('saved fig3_tunability.png')
119
120 if __name__ == '__main__':
121     fig_spectrograms()
122     fig_decay_and_rt60()
123     fig_tunability()

```