# Economical audio attenuator: Linear to log pot mod[i]

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Level (volume) controls in analog audio are mostly simple variable resistors – *potentiometers*. For consumers, they have been the most essential control with which humans interface. For electronic musicians, audiophiles, and audio professionals, their performance and "feel" are even more important. Whether in the form of rotating or linear faders, operating these can feel quite differently from the sound they make. *Mis-tracking*, they pan sounds erratically while fading up or down. Even at one setting and not used actively mixing, the *imbalance* between channels ruins the stereo soundstage. Poppycock prevalent on the internet isn't helpful.[ii] But a simple engineered solution is "at hand!"

The "pot," as it is nicknamed, for sound is often made splicing two straight-line resistances, orange in the chart, one for each half of rotation. (Also flattened at the very top, hinting a backwards Z, it is known as "Z-taper.") At 50% of travel, the corner is at 10% voltage gain (90% loss). At this point, the output is 20dB lower than at the maximum setting, perceived as about ¼ of maximum loudness. (Every ~10dB of change, up or down, is perceived as halving or doubling loudness.) But moving within either straight-line region of this common so-called "audio taper" potentiometer does not perform as an ideal audio "fader," and therefore it does not give the feel to match the sound heard while using it.

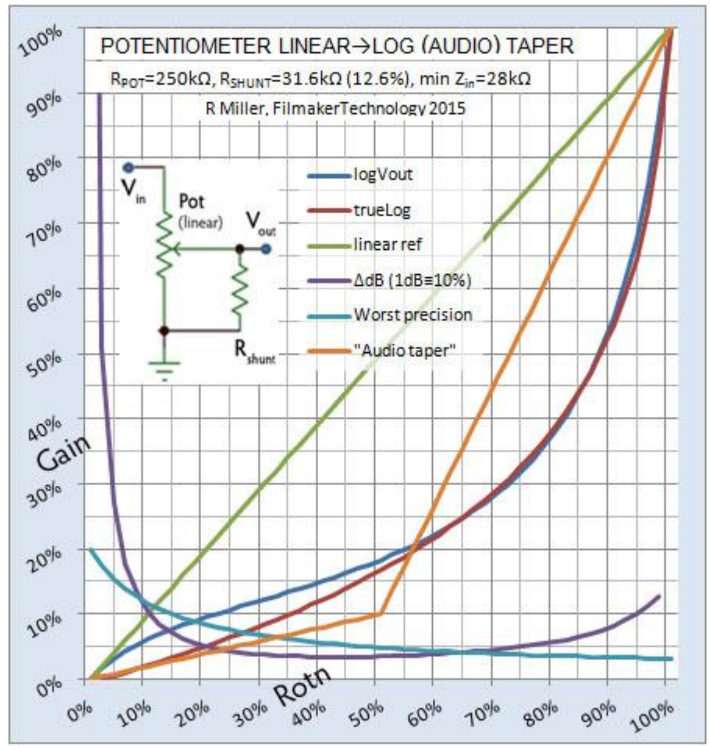
Ideally, an audio fader would accelerate smoothly in dB per degree of rotation. Plotted in percent gain (loss), it would appear logarithmic (exponential), as shown in red. Splicing two straight lines is a cheaper but cruder two-piece approximation, the sound rising a too slowly, then abruptly taking off too fast. A better characteristic is desirable for actively controlling audio volume.

Historically broadcasters used "step-attenuators," dB-calibrated rotary switches expensively made with 24 or more contacts and precision resistors calculated to piece 24+ shorter lines together for a much closer to ideal log curve. More recently, linear audio faders with 45, 60, or 100mm travel are used, but can still suffer unnatural climb in volume, and mistracking/imbalance if stereo. (Professional consoles use voltage-controlled amplifiers (VCA) for precisely exponential level control, or DSP where audio gain at every incremental change in loudness is digitally calculated.)

For hobbyist or pro, a nickel (literally) solution works well that simply adds a resistor to the pot. This trick has been performed for decades, but is usually compromised to reduce its low, erratic loading. However ubiquitous low impedance op-amps suggest a revisit. The chart's blue curve shows tack-soldering a 1% metal film resistor that costs pennies between a common *linear* pot's wiper (center contact) and its CCW terminal, signal common. The pot alone would mostly follow the straight green line, shown for reference. While others give a range of 10~20%, a resistor 12.6% of any linear pot's value and feeding a much higher following impedance produces the blue curve the author finds optimal.

The disadvantage is less than ideal performance below mid rotation, even though better compared to Z-taper. Nothing better can be had for this easy a solution. In reality, the linear pot's transfer function is shaped like a *lazy-S* (thus termed "S-taper") that improves this solution a bit, lowering the blue curve toward its extreme left (not shown) thus achieving silence somewhat more smoothly. A pot's lower portion is used most while fading a sound up or down – volume controls seldom see the top end of their range. Unless of course a setting of "11" is demanded!

For mostly fixed level settings, this modification offers an even bigger advantage: A cheap dual audio (Z-)taper pot with specified tolerance of ±20% might wreak havoc on stereo balance, causing as much as 5dB difference between channels, and varying with setting. (As a fader, this error might unintentionally pan a sound between speakers, for it only takes 15dB to pan a sound totally to one speaker [Theile 2001]). However with a 1% resistor , the cyan curve shows the attenuator's lowest operating range now has precision of 10% (worst case less than 2dB difference between channels), but for most of its range it is less than 5%, or less than 1dB difference. While most pots are often specified as 20% precision, and precision resistors 1%, these are worst case figures, and their performance typically can be better. So stereo tracking and imbalance with this modified attenuator can be expected to be mostly within a fraction of a dB, especially if parts are channel-matched, and very little or no imbalance will be perceivable.




Values are scalable, and need be accurate within only a couple %. The values shown were for a vacuum tube restoration, but a solid state design could manage a 25kΩ pot and 3.16kΩ resistor, with 2.8kΩ minimum load of the prior stage (11% of pot value). The load following the attenuator must be at least 10x the resistor, or the resistor value increased for a parallel equivalent of 12.6% of the pot value. Gain at mid-rotation is –15dB, 3dB more than the log ideal, but improved over that of the orange Z-taper pot.

In feel, despite the increasing departure from pure log through its bottom half of travel, this attenuator has nearly equal dB steps per equal changes of rotation through all but the very bottom 1/8 and top 1/16 of its range (purple curve, where 10% is 1dB), but is better at these extremes with the S shape. In the remaining 240º of a typical pot's total 300º range it is mostly ~½dB for every 2% change in rotation. Except for the softest levels during fading out or in to or from silence, this attenuator will feel like it sounds for most PA, recording, webcasting, and electric guitar applications. And it can be retrofitted for very little effort & expense. # ;<{)#

[i] More papers on vinyl play, Ambiophonics, subwoofers, full-sphere 3D at [www.filmaker.com](http://www.filmaker.com)

[ii] Beware wrong info or misleading presentation online. A good reference is Texas Instruments' - https://e2e.ti.com/blogs_/archives/b/thesignal/archive/2012/10/22/logarithmic-potentiometers