ELECTRONOTES
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APPLICATION NOTE NO. 431

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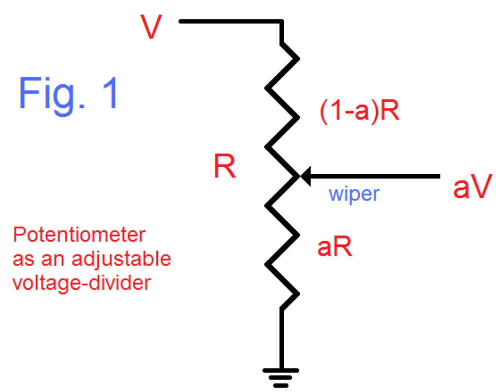
AUDIO VOLUME CONTROLS

Back 50 or 60 years ago, radios were simple AM sets, usually the "5-tube Wonder" superhet designs*. They had two controls, a combined Off/On-Volume knob, and a Station knob. Obviously they were purely analog. The volume control had a power switch which snapped on as soon as you rotated the control clockwise. You did have to wait 30 seconds for the radio to warm up. Once a station was tuned in (or usually, had been previously tuned to a favorite station) the volume was adjusted to a comfortable level with the potentiometer on the control's shaft. This volume control worked exceedingly well. Today's volume controls – not so much! Why?

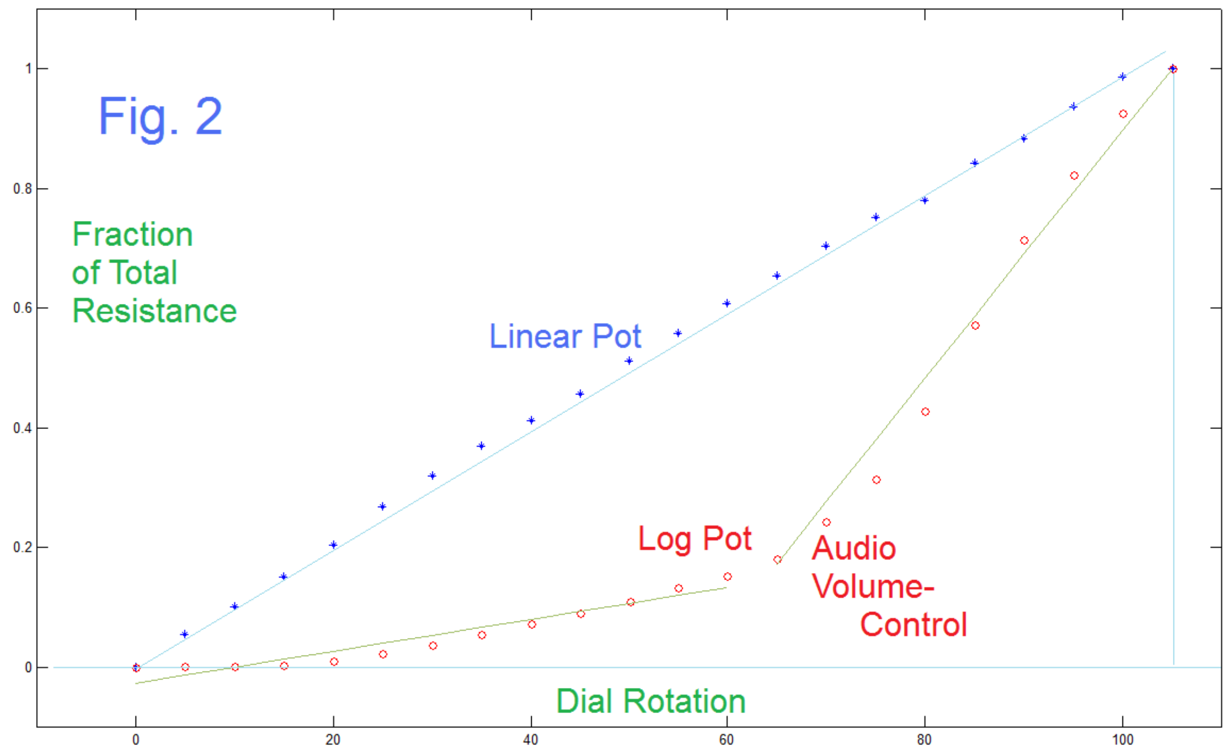


The old fashioned volume control was a basic potentiometer set as a voltage divider, basically as in Fig. 1, which is likely familiar to all reading this. It has three terminals, two end contacts and the center "wiper" which is the adjustment. Thus the output voltage varies as aV, from 0 to V as the position of the wiper varies from low to high. What may not be recognized is the relationship between the position "a" as it is <u>electrically</u> considered and as it is <u>mechanically</u> considered. When we draw a pot on a schematic, we likely always <u>draw</u> the wiper as being close to the middle, while knowing full well it could be anywhere between the ends. In fact, the full rotation is about 270 degrees. The question is, when it is rotated 270/2=135 degrees, is a reasonably close to 0.5?

The answer is yes if it is a linear pot, as it probably most often is. The alternative is what is known as a "log pot", or an "audio pot". You probably can't tell the difference – what they call the "taper" - from looking at it. To be sure, make a pencil line on the end of the shaft, and twist it a few times to get it to what you judge to be half rotated. This

* If you have one kicking around, get rid of it. They were and still are dangerous if you actually plug them in. Likely they would be illegal today. They had no power transformer. The filaments were in series (50 volts, 35 volts, and three 12 volts) directly across the 120 AC line. Unless you had a polarized plug, there was a 50:50 chance the radio's chassis would be 120 volts hot. (Many that did have the polarized plug had the plug filed down since polarized <u>sockets</u> were rare.) Touch the metal chassis and a water pipe and you were at best, painfully shocked. In theory, a wood or plastic cabinet prevented you from doing this, but some had no such protection.

does not have to be exact. Measuring the resistance between the ends, you should get something close to the nominal value of the pot (perhaps 10k or 200k, etc.). Next measure the resistance between each end and the wiper. Either these two values will be reasonably close to being equal (linear), or they will be quite different (see Fig. 2), like 90%:10% (instead of 50%:50%) if audio.

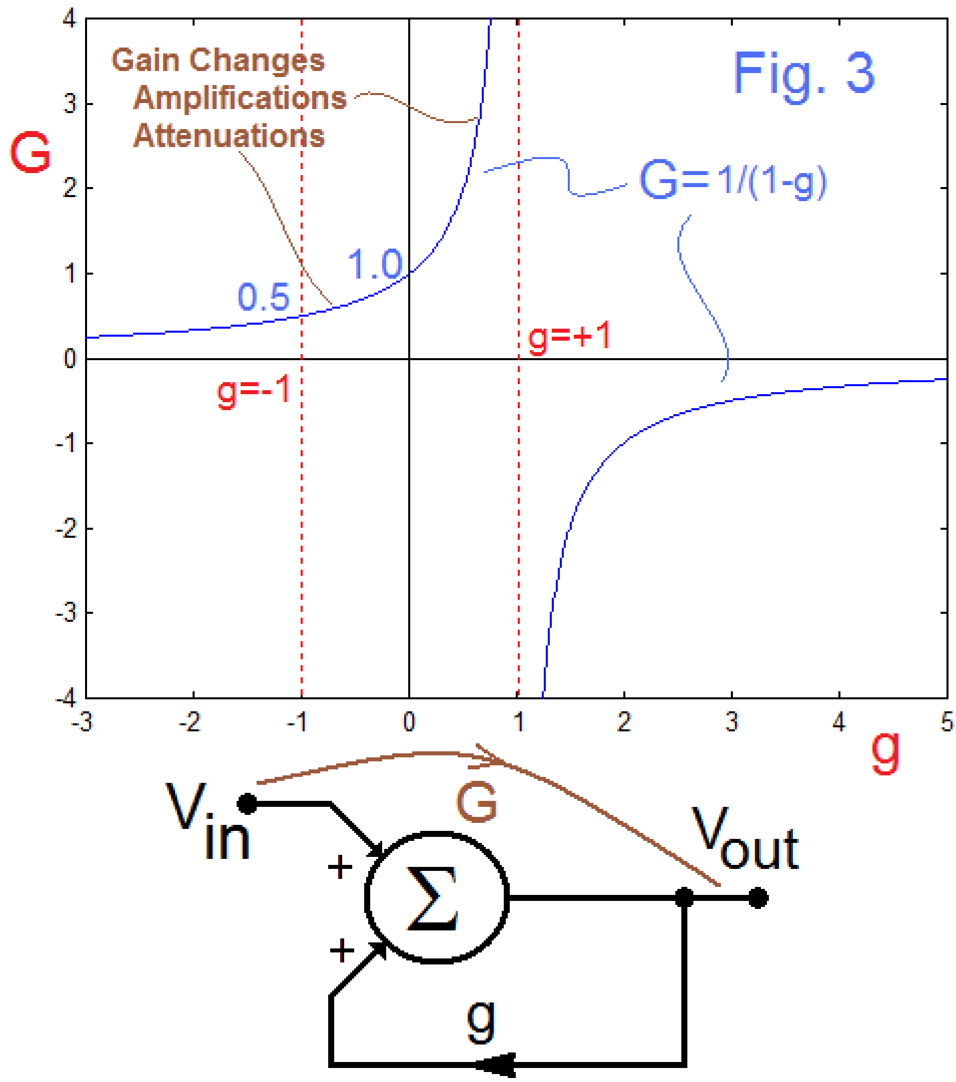


The two plots of Fig. 2 were obtained experimentally by attaching a dial and knob to two pots from my stocks, one says it is a 10k linear plot and the other a 15k audio pot. The dial was set to zero for full counter-clockwise rotation, and the full clockwise rotation extended just beyond the marks labeled 1 to 100. The resistance at dial settings 0 to 105 were taken spaced 5 apart, giving 22 data points for each pot. The two resistances were scaled as fractions from 0 to 1. There is a clear difference between the two types. This is the first time I have actually measured this!

In a moment we will make it clear why we would ever want a log (audio) pot. Here we note that I have always believed that there was no such thing as a log pot, but rather a taper composed of two linear segments of quite different slope. To consider this I have fit (least squares) straight lines to the first half and second half of the log response. This result does suggest that the two slope notion may be correct, although not exactly. (For comparison, the linear pot result does indicate that quite good linear segments are possible.) Note a previous discussion of this issue and a ploy of using a load on the wiper to achieve a log-like shape from a linear pot [1].

Why do we want a log-like response for audio anyway? Because of the log-like loudness response of the ear [2]. This goes back to my complaint about the inconvenience of modern (digital) volume controls. I have, for example, a very nice Internet radio. I love what it offers, but the volume control is a default function of the main control knob, and clicks up in steps which display on the screen. For me, as I use it, one or two clicks are not loud enough, but three is just a bit more than I want. More than three of four are not that different. The volume seems to be linear with the clicks. It is a clear case of wasted resolution. A volume control really should have more resolution at the low levels.

So much for a rant. A related topic follows:



Onward to address misunderstandings about positive feedback [3, 4]. When we put feedback around an amplifier, we change the gain. Negative feedbacks decreases the gain while positive feedbacks increase the gain (Fig. 3). Recently there has been discussion and considerable misunderstanding of this with regard to some climate models [4]. One issue is with regard to how large the positive feedback can be if we want to have stability, and in particular with regard to well-engineered electronic circuits. The fact is that electronic circuits are limited to positive feedback gains of less than +1 (Fig. 3), not to 0.1 as one blogger contends, and can approach +1 if we are aware of component sensitivity. This is a matter of standard EE practice.

A second issue relates to non-linearity. Note that the red plot in Fig. 2 is by definition and by terminology (log) not-linear. We notice a vague similarity between the low-pot and the feedback gain curve of Fig. 3. This curve is not linear either: it's G =1/(1-g). An amplifier whose gain is controlled by a volume control as in Fig. 2, OR by the feedback gain as in Fig. 3, is either linear (usually very near linear) or non-linear regardless of the setting. IT'S JUST A DIFFERENT CONSTANT MULTIPLIER. The same applies to my Internet radio that is a non-linear control (it steps). This is quite obvious.

The confusion (same blogger) is that of not realizing that we look at the issue of linearity in terms of an input/output relationship (like an amplifier's transfer function) [5]. The abscissa in Fig. 2 and Fig 3 is a control parameter setting (not an input signal), and the ordinate is a resulting gain (not an output signal).

REFERENCES

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[2] B. Hutchins, "Why No Range-Switch with Hearing?",Electronotes Application Note No. 428 July 10, 2016 http://electronotes.netfirms.com/AN428.pdf

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