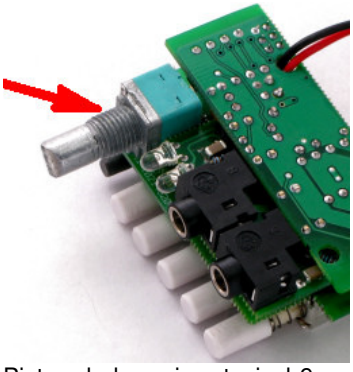
PRACTICAL DEVICES
CORPORATION

Channel Imbalance in your Volume Pot - Some Thoughts

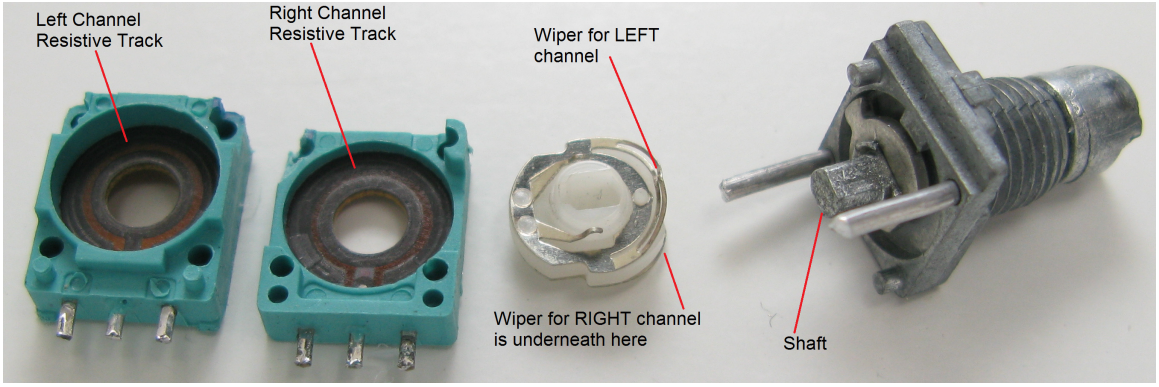
The volume pot is a fairly critical component of any audio amp; since we deal with pots by the bucketful, I thought I'd share a few tidbits of insight with the headfi community. Please don't view the following as shilling for our amps; we here at Practical Devices have received alot from the online community and members here, and I'm just giving a little back. Hopefully this will be particularly helpful to the DIY'ers, or those hard-core breed of folks who roll their own pots in their commercially-bought amps.

I'm only dealing with *analog* pots here, not digital pots, nor stepped-resistor pots.

I'll assume you know the pot basics - a pot consists of a "wiper", which scrapes against a resistive track as you turn the knob. For those who need all the pot info they can get, check out the useful wiki article: http://en.wikipedia.org/wiki/Potentiometer



Pictured above is a typical 9mm pot, shown in its natural habitat inside the XM5 headphone amp. The 9mm refers to the pot's body size. It is a mechanical "**dual-ganged**" pot, consisting of two isolated sets of wipers, which scrape against two isolated sets of tracks of resistive material. "Dual-gang" means the pot consists of two separate potentiometers (one for the left audio channel, one for right) which share the same shaft



Above is the pot broken apart. Note there are two separate channels (one for left, one for right). **Also very interesting**: note that *each* channel has *TWO* wipers for redundancy (it's a little hard to see in the picture, as I've accidentally bent the two wipers so they are touching each other). This helps reduce any crackle or dropout when moving the pot, since at any time, at least one of the wipers *should* be in contact with the resistive track.

Also, from the above picture, it is obvious that any dust getting into works would be very bad. Dust will get in between the wiper and the resistive track, and will lift the wiper off the track, losing electrical contact. Fortunately, these pots are fairly well-sealed, so it has never been an issue.

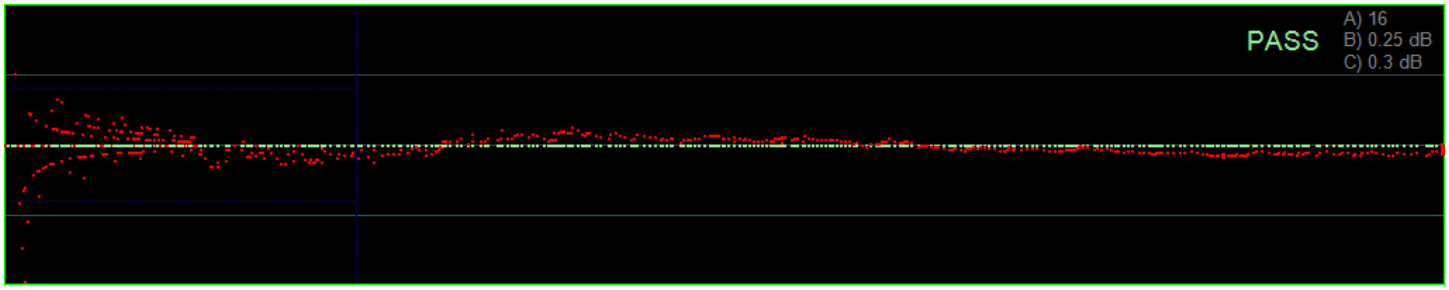
What makes a lousy pot lousy? I won't delve into the obvious: flimsy construction, crackling/cutout, open to dust, a wobbly shaft, etc. For us, the biggest problem is **channel imbalance** (aka channel mismatch); I find it fairly irksome to slap on a set of headphones and hear one ear louder than the other, my degree of irkedness being directly proportional to decibels of imbalance. The usual culprit is the volume pot. ***ALL*** analog pots, without exception, suffer from some degree of imbalance. Being mechanical devices, it can't be avoided. So the goal for us is to *minimize* the imbalance.

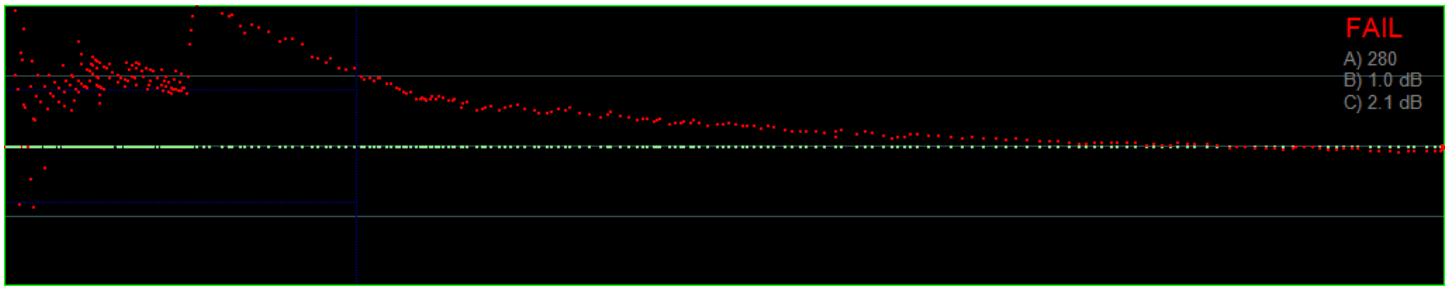
The difficulty for us, as amp designers/manufacturers, is getting pots with good channel matching ***which are small enough*** to fit in our portable amps. There are two things causing imbalance here:

1) Due to mechanical tolerance (slop), the left channel wiper will never be *exactly* in the same position as the right wiper, and,
2) Even if the two wipers *were* exactly in the same position along their respective resistive tracks, the tracks themselves won't exactly match each other - the two tracks will not be attached to the body of the pot in exactly the same place, and the *composition* of the two tracks (ie. percent carbon content, which give the tracks their resistivity) will be slightly different. And finally, for a pot with an "audio taper", the resistivity of the track itself (ie. "ohms per millimeter") has to vary with position - very very difficult for the pot maker to match.

Size does matter here, since for a given mechanical and resistivity tolerance, a pot with a longer resistive track will have proportionally better matching than that with a shorter resistive track (and a longer track means a physically bigger pot). Thus the problem with physically small pots.

So, what to do?
We've resorted to testing our pots, before they get installed into our products. The good ones get installed, the bad ones thrown out. Since we do it on a semi-industrial scale, we have a test jig and ultra-cool software to speed things up. Here's an example of a good pot vs. a bad pot (both pots were from the same batch).





The Y-axis is dB of channel imbalance. The X-axis is (a non-linear representation of) percent rotation of the pot shaft. The left side of the graph is with the shaft at 0% rotation, and the right is 100%.

The green line represents the left channel, and the red is the right. The distance between the red line and the green line is how many dB of channel imbalance exist (graph is 1.0 dB/division. Ignore the noise on the far left side of the graph - this is an artifact of the low-res and noisy ADC on our duct-tape-encrusted test equipment).

The "PASS" pot is nice and well-matched, with less than 0.3dB of channel imbalance. Pretty good.
The "FAIL" pot has, for a small portion of its rotation, a spike of about 2dB of imbalance. So if you are listening to music and happen to have the volume knob right at the spike, one ear will be 2dB louder than the other. Ugh.

These particular pots are spec'd at a tolerance of "±20%", which is typical of 9mm pots. 20% is, of course, quite flimsy; even the "FAIL" pot above meets that. But a 2dB imbalance would be noticeably by most, so we chuck it into the garbage.

So, the take-home message for the DIY'ers installing your own analog pots: TEST THEM FIRST.

If your pot only costs $2 or $3, then consider buying 3, and use the best one. You don't need fancy test equipment like we have; simply use an ohmmeter to measure the resistance for various rotational positions, and if the left channel resistance is always within a couple of percent of the right, you're golden.

Comments welcome.

Regards,
James
www.practicaldevices.com

PRACTICAL DEVICES
CORPORATION