

Howdy!

I often am asked which value of potentiometers (or “pots”) works best for a given pickup. This month’s tech tip will provide you with a functional understanding of pots that may be helpful in selecting the model and value best suited to your application.

**But first, what are pots and what are they used for?**

A **potentiometer** as used in guitar and bass control circuits is a three-terminal variable resistor with a rotary sliding contact. Pots used in musical instruments often have a single turn rotating shaft (this shaft rotates just under 360 degrees) and three tabs used to make electrical connections to other components in the controls circuit. Pots are sold by a variety of manufacturers and come in nominal values such as 250 k-Ohm [250,000 Ohm], 500 k-Ohm and 1 M-Ohm [1,000,000 Ohm]. Pots can be specified as linear taper, log taper or audio taper.

As one rotates the shaft of a pot, the sliding contact, or wiper, moves across a resistive element that is manufactured in the shape of a circle. This resistive element can either be a coil or a carbon resistor. For the purpose of discussion, let’s call the left most tab of a pot “A”, the middle tab “B” and the right most tab “C”. If a pot has a nominal DC resistance value of 250 k-Ohm and the shaft is at one end of travel, the resistance between two adjacent tabs (A and B for example) will read the maximum value (approximately 250 k-Ohm) and the resistance between the center tab B and tab C will read a small value such as 0.1 k-Ohm.

Pots are most commonly used in a guitar controls circuit to control the volume and tone of the output from one or more pickups. As a volume control, a pot is used to “split” the signal coming from a pickup, sending part of the signal on ultimately to the output jack of the instrument, and the remaining part of the signal to electrical ground where it effectively “disappears”. As one rotates the shaft of the volume pot, the amount of the signal that is shunted to ground changes, and volume is controlled. In a tone control, a pot is used in conjunction with a capacitor to selectively allow certain frequencies in the output signal from the pickups to be shunted to ground. The topic of tone control will be the subject of a future Tech Tips.

**What is the actual performance of a pot?**

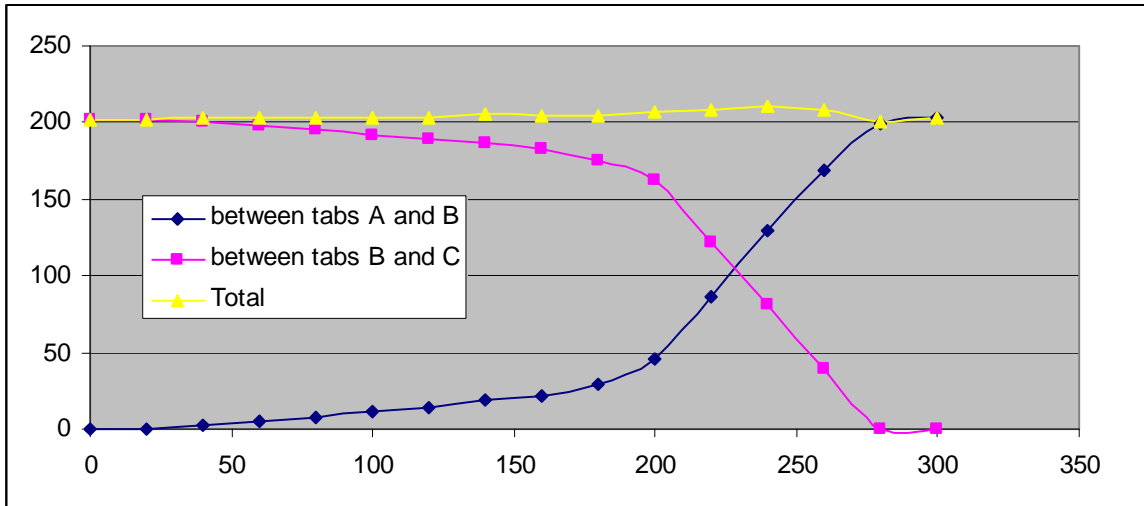
To investigate the behavior of a “standard” pot I measured the DC resistance (DCR) between tabs A and B and between tabs B and C as a function of shaft rotation. I used a nominal 250 k-Ohm audio taper pot manufactured by CTS for this experiment and measured DC resistance using two Fluke 10 multi-meters; here are the results:

Table 1: Measurements of DC resistance (DCR) as a function of shaft rotation and calculated value of total DCR.

Rotation [Degrees]	DCR [k-Ohm]		DCR [k-Ohm]
	between tabs A and B	between tabs B and C	Total
0	0.4	201.8	202.2
20	0.4	201.8	202.2
40	2.3	201	203.3
60	5	198	203
80	8.1	195.2	203.3
100	11.4	192	203.4
120	14	189.4	203.4
140	18.7	186.5	205.2
160	21.9	182.9	204.8
180	29	175.1	204.1
200	45.2	162.1	207.3

240	129.4	80.7	210.1
260	168.5	39.6	208.1
280	199.7	0.2	199.9
300	203	0.01	203

Figure 1. Plot of DC resistance as a function of shaft rotation and calculated value of total DCR:



There are a few interesting things to note from this data:

1. The total rotation of the shaft of the pot was approximately 300 degrees- this is 60 degrees less than one full rotation.
2. The total DCR calculated by summing the resistances measured between tabs A and B and between tabs B and C at all shaft rotations was less than the nominal value of 250 k-Ohm.
3. The DCR measured at both ends of travel for the pot was not zero.
4. DC resistance changed slowly at first (between 0 degrees and 180 degrees) as the shaft of the pot was rotated clockwise, then the rate of change in DCR increased between 200 degrees and 280 degrees, then slowed again between 280 degrees and 300 degrees. The point at which the DCR measured between tabs A and B and between tabs B and C occurs at approximately 235 degrees of rotation.

### OK, enough technical stuff. How does one select an appropriate pot?

#### 1. Volume control pots.

Given that the maximum DC resistance of a pot used in a volume control is not infinite, some of the signal from the pickups will leak through a pot to ground even when the pot is set to full volume. A volume control pot with a nominal 250 k-Ohm DCR will only allow approximately 0.04% of the signal to leak to ground; a nominal 500 k-Ohm pot will only allow approximately 0.02% of the signal to leak to ground. This difference may not sound like much, but many guitarists can hear the effect. Traditionally, 250 k-Ohm pots have been used in the volume control circuits for instruments which have single coil pickups with relatively low DC resistance (typically 5 to 8 k-Ohm); 500 k-Ohm volume control pots are often used in instruments that have humbucking pickups of higher DC resistance (which often are 8 to 16 k-Ohm in DCR). Audio taper pots are most often used for volume control as the taper provides a more "natural" feel than a linear taper pot of the same DCR value would.

#### 2. Tone control pots

Historically, 250 k-Ohm audio taper pots have been used for tone control in instruments that have single coil pickups. Similarly, 500 k-Ohm pots have often been used in instruments that have humbucking pickups. These selections are made based on two factors. First, is the relatively low DC resistance of single coil pickups as compared with humbucking pickups. When the tone control in an instrument with single coil pickups is set to full (no intended reduction of treble frequencies) some of the guitar signal "leaks" through the tone circuit to ground. In an instrument that has a high treble frequency content (as many single coil instruments do) this can be a good thing. In instruments with humbucking pickups which tend to have reduced high frequency content, loss of treble is to be avoided through the use of 500 k-Ohm or even 1 M-Ohm tone control pots. Secondly, the range of frequencies removed by the tone control circuit is determined both by the DC resistance in the tone control pot and the value of the tone capacitor. The next Tech Tips will go into this subject in more depth. In general, 500 k-Ohm tone control pots tend to function best when paired with a tone control capacitor having a value of 0.022 micro-Farads; 250 k-Ohm tone control pots tend to function best when paired with a tone control capacitor having a value of 0.047 micro-Farads.

I hope this information is helpful to you.

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