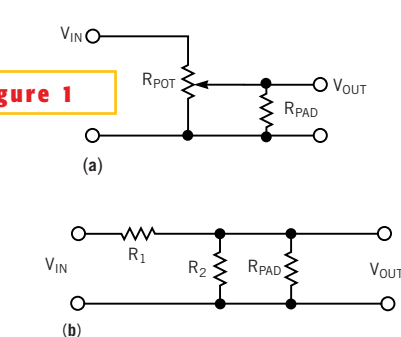


# Tack a log taper onto a digital potentiometer

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IT'S SOMETIMES CONVENIENT to have digital control of the volume level in an audio system. The use of multiplying DACs (MDACs) is problematic because of the switching noise of the ladder network. This noise comes from the bit switches injecting charge into the signal when they turn on and off. Audio engineers have dubbed this noise “zipper noise” from the sound that results from dynamically adjusting the volume (gain riding). An alternative to an MDAC in this application is a digital potentiometer, such as the Analog Devices AD52XX, AD84XX, or AD7376. You can think of the digital potentiometer as a tapped resistor string. It generates less noise because fewer switches change state. In addition, you can connect the three terminals of the potentiometer anywhere within the common-mode range of the circuit (the supply-voltage range), unlike an MDAC, which generally uses ground as reference.

The primary drawback with using the digital potentiometer for volume control is that it currently comes with only a linear taper. With a linear taper, if the “wiper” is at the midpoint, the signal is only 6 dB less than the maximum. Thus, most of the adjustment range occurs



**Figure 1** Adding a pad resistor to a digital potentiometer imparts a logarithmic-like taper to the device.

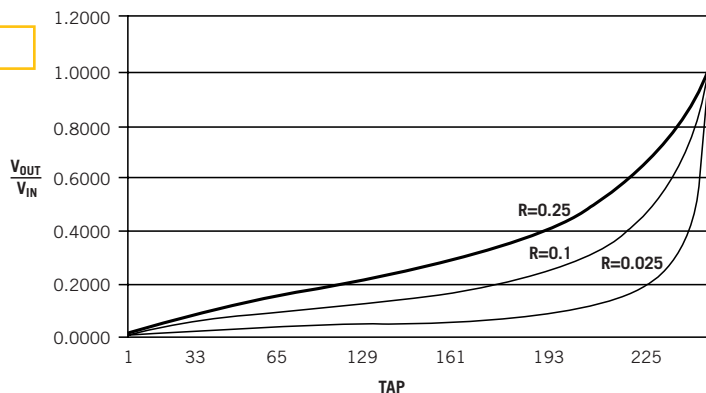
within a small percentage of the range of the potentiometer. This constraint limits the adjustability of the volume setting. The ear responds logarithmically; the volume control should respond similarly. The primary reason for having only a linear taper is the manufacturing problems that the large range of resistance values for a log taper cause. By adding a pad resistor from the wiper of the potentiometer to one end (Figure 1a), you can to simulate a log taper. If you split the potentiometer into two resistors,  $R_1$  and  $R_2$ , you can redraw the circuit as in Figure 1b. The output voltage then depends on

the parallel combination of  $R_2$  and  $R_{PAD}$ . You define a ratio,  $r$ , which is  $R_{POT}/R_{PAD}$  ( $R_{POT} = R_1 + R_2$ ). By adjusting the value of  $R_{PAD}$ , you can modify  $r$ , which adjusts the taper, or the attenuation-versus-digital-input code to suit the application. The following expression gives the transfer function of the potentiometer:

$$\frac{V_{OUT}}{V_{IN}} = \frac{R_2 \parallel R_{PAD}}{R_1 + R_2 \parallel R_{PAD}}$$

Figure 2 shows the attenuation curves for three values of a pad resistor. As you can see, this trick doesn't give a taper that is so many decibels per step, but it does allow for better low-level settleability. You must address a couple of issues. The first is that the end-to-end resistance of the potentiometer changes with the digital code. It varies from the potentiometer resistance at one end (with the wiper at the lower end) to the value of the pad resistance in parallel with the potentiometer resistance at the other end. If you configure the circuit as a typical attenuator and drive it from a low-impedance source, the low pad resistance should not present a major problem. If, however, you are trying to obtain a set resistance value to determine a time constant (or any other application in which the resistor value is critical), this approach may not work well. The second issue involves overvoltage. The three terminals of the potentiometer can be anywhere within the supply range of the IC, which is 5V for the AD52XX and  $\pm 15V$  for the AD72XX family. If you apply overvoltage to one of the pins, even in a transient condition, the IC could latch up because of a parasitic substrate SCR. (DI #2473)

**Figure 2**



It's not log, but it's close. These curves approximate what you can obtain from an audio-taper potentiometer.

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