Application Report
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DirectPath™ Ground Centered Headphone Amplifier

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ABSTRACT

A DirectPath™ amplifier is an amplifier where the signal is centered with respect to ground (or, a ground centered amplifier). Ground centering avoids the need for large DC blocking output capacitors, saving board space and cost. This application report compares traditional headphone amplifiers to DirectPath amplifiers.

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Trademarks

DirectPath is a trademark of Texas Instruments.

1 Traditional Headphones

To understand the advantages of ground centered headphone amps, first understand how traditional headphone amplifiers work. Traditional headphone amplifiers operate on a single rail voltage (Vdd). Because it operates off a single rail, the highest possible output voltage of the amplifier is Vdd and the minimum possible is ground. In order to get the maximum possible swing, the amplifier must be DC biased (centered) halfway between the maximum and minimum, which is Vdd/2. Headphones, however, can be damaged by a DC signal. In order to prevent this, a high-pass filter must be used to remove the DC bias. The filter is created by adding a capacitor in series with the headphones, which normally have a resistance of 16 Ω. Figure 1 shows the amplifier configuration and effect on the output signal.

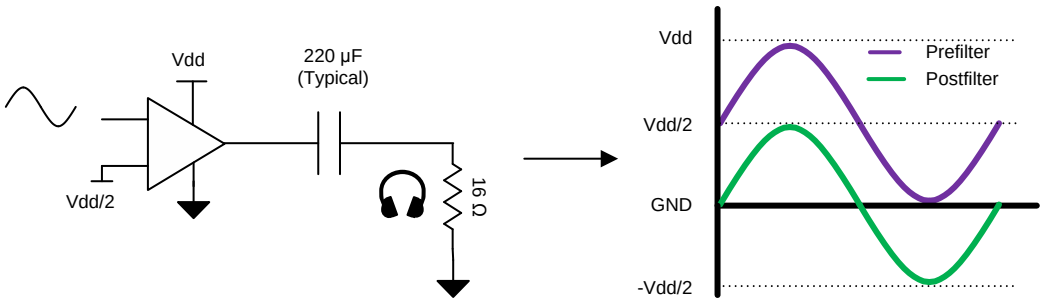

Figure 1. Traditional Amplifier Configuration and Output Signals

The cutoff frequency of a high-pass filter determines which signal frequencies are attenuated and which frequencies are unaffected. The gains of all signals with a frequency below the cutoff frequency are attenuated so they cannot pass through the rest of the system. Frequencies above the cutoff frequency are unaffected by the filter. A DC signal is a signal with frequency equal to zero. Equation 1 shows how to calculate the cutoff frequency of the high-pass filter:

$$f_c = \frac{1}{2\pi R_L C} = \frac{1}{2\pi(16\ \Omega)(220\ \mu F)} = 45.237\ Hz \quad (1)$$

In order to remove DC bias, the cutoff frequency simply needs to be greater than zero; the problem with this, however, is the closer the cutoff frequency is to zero, the larger and more expensive the required capacitor is. The low-frequency bass range is 20 to 60 Hz, so the smaller the capacitor used, the more bass response is cut off. A normal compromise is to use a 220-µF capacitor, which will cut off frequencies below 45 Hz. Capacitor sizes vary from application to application and is more heavily influenced by system specifications. Figure 2 shows how the frequency response of a headphone is affected by the high-pass filter.

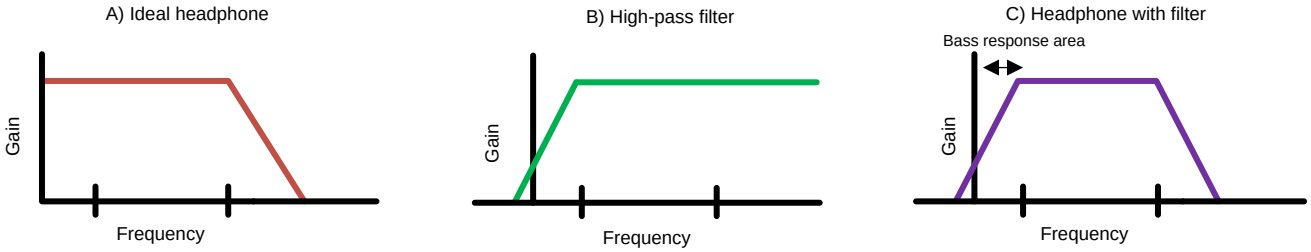

Figure 2. Frequency Response of: (a) Ideal Headphones, (b) High-Pass Filter, and (c) Headphones With Filter Output

2 Ground Centered Headphones

Ground centered amplifiers use additional circuitry around the amplifier to remove the need for both a DC bias, and therefore output capacitors, while still using a single supply. This is done by using an integrated charge pump. The charge pump takes the supply voltage Vdd and reverses the polarity to –Vdd. These values become the maximum and minimum output values for the amplifier, centering the output at ground and allowing twice the swing of a traditional amplifier.

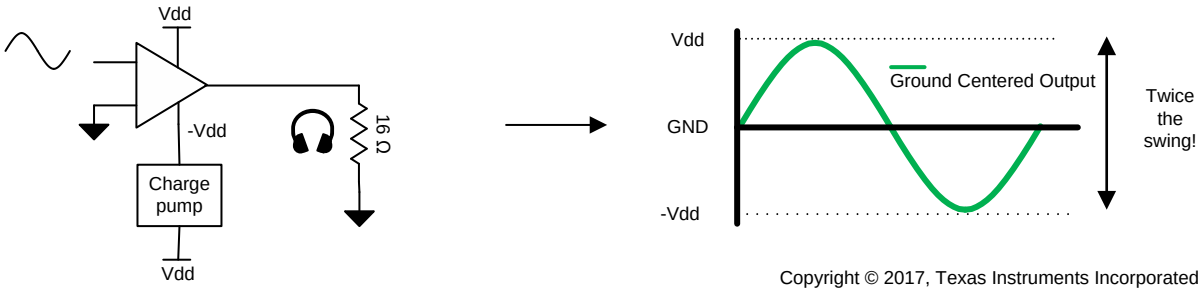

Figure 3. Ground Centered Amplifier Configuration and Output Signal

3 Summary

Ground centered headphones:

- Remove the need for output capacitors saving space and cost
- Improves bass response
- Removes pop and click effects associated with a DC bias

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