



APPLICATION NOTE 2980

Circuit Refinements Ensure Quality Audio in Portable Devices

Abstract: This article examines key parameters affecting headphone amp performance including: PSRR, turn-on transient suppression, and PCB grounding. It focuses on one application (the headphone amplifier) and uses the MAX9724 and MAX9728 headphone amps.

The challenge for audio designers is to make high-performance, low-noise analog circuitry coexist with ASICs, processors, and DC-DC converters. Consider, for example, the issues affecting just one component in a typical audio replay chain—the headphone driver.

The typical headphone driver must drive a low-impedance load (typically 32Ω ; sometimes as low as 16Ω) with a signal whose amplitude ranges up to $1V_{RMS}$, while preserving the dynamic range of the source material. That may seem like a simple task, but closer examination yields some harsh realities:

- The headphone output must maintain this dynamic range when powered by a single-supply voltage, which is usually derived from a DC-DC converter and shared by high-speed digital circuits.
- Given the signal amplitudes and load impedances encountered in these circuits, current peaks drawn from the supply can range up to 90mA.
- When shutting down the supply or the headphone driver, clicks or transients should be inaudible.

Power-Supply Noise

To realize a reasonable signal-to-noise ratio (SNR) you must suppress the effect of power-supply noise on the headphone amplifier output. Power-supply rejection (PSRR) in the headphone driver is essential for that purpose.

For example, the dynamic range for CD- or DVD-based material can exceed 90dB. Assuming a noise component of 100mV riding on the audio power-supply voltage, with most of its spectral content residing in the audio bandwidth, the noise at the headphone output must be reduced to about $30\mu V$ to maintain the 90dB dynamic range. Effectively, the headphone driver's PSRR must exceed 70dB at the frequency of interest.

To achieve such power-supply rejection across the audio band, a careful design approach is necessary, with particular attention paid to the amplifier's suppression of power-supply noise over frequency. A glance at most op amp data sheets shows that PSRR is usually high near DC; it drops dramatically as frequency increases (usually at -20dB/dec). At 20kHz some parts exhibit a PSRR less than 40dB.

Some DC-DC converters produce higher noise components at the upper end of the audio frequency spectrum. Though arguably less audible at those frequencies, the resulting noise at the headphone outputs is still measurable. Note that most data sheets for audio DACs or CODECs featuring on-board headphone drivers rarely draw the reader's attention to the PSRR specification. If PSRR is offered, it usually appears as a single entry within the electrical characteristics, rather than a curve of PSRR vs. frequency.

Because most headphone amplifiers lack sufficient PSRR, an external low-dropout (LDO) regulator is typically added to clean up the headphone amplifier's supply voltage. To achieve sufficient PSRR at the audio outputs of a notebook PC, for instance, where +5V is still a common supply voltage for audio circuitry, certain nodes are often regulated down to 4.7V or so.

ICs such as the [MAX9724](#) and [MAX9728](#) increase the PSRR well above levels commonly achieved with other

methods. These headphone amplifiers apply internal subregulation to key nodes within the device, effectively eliminating the need for an additional LDO.

Suppression of Clicks and Pops

Click/pop suppression usually describes the ability of an IC to minimize the abrupt and often disconcerting transients that occur when the IC is muted or powered up (or down). That behavior is difficult to achieve in an output driver, for which no downstream circuitry can be muted to mask impending abnormalities. If the headphones are plugged in, then whatever is driving them inevitably makes or breaks the transient performance of the audio system.

Headphone drivers are usually powered from a single supply, and the outputs are AC-coupled to the jack socket with large DC blocking capacitors as shown in **Figure 1**. That arrangement prevents the DC voltage from developing across the headphones. During normal operation, the blocking capacitors have a DC voltage across them, since the headphone side of the capacitor is at ground potential and the amplifier output has a DC level that is biased to approximately $\frac{1}{2}$ of the supply voltage. The capacitor must be charged to its working DC voltage when power is first applied, but the charging current also must flow through the load (the headphone voice coil). What can prevent this current from producing an audible signal?

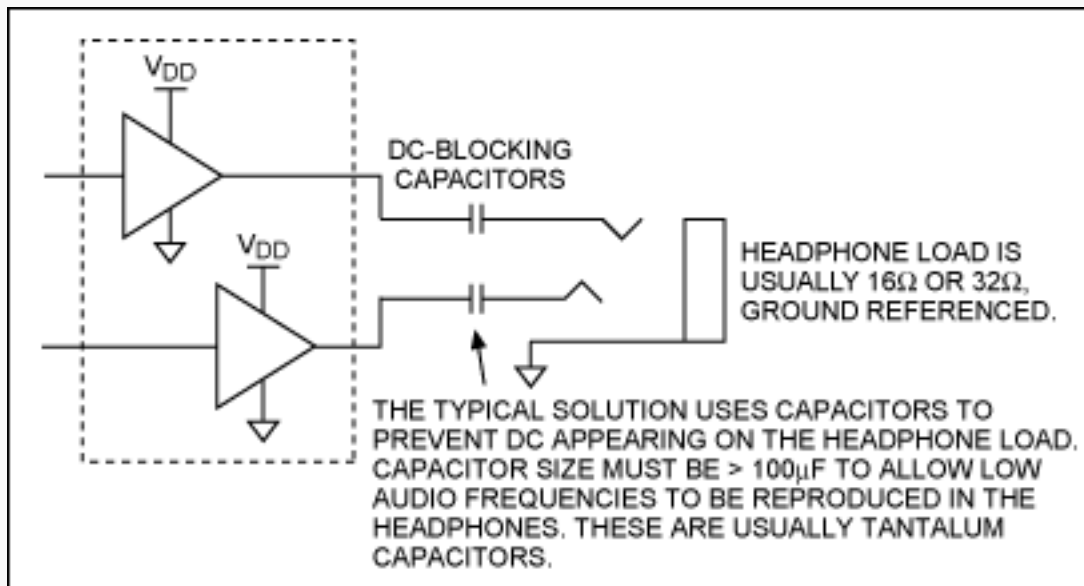


Figure 1. This circuit, the usual configuration for a headphone driver in a single-supply application, includes series capacitors that form a highpass filter with the headphone impedance (necessary to block DC from the headphones).

Some designs suppress this charging current using JFETs and discrete components around the output of the amplifier. Others designs provide an RC time constant to slow the turn-on transient. This approach reduces the annoyance factor by lowering the frequency content of the disturbance. At least one product employs a back-to-back exponential ramp (with S-shaped profile) to further suppress the pops caused by power up. Unlike the RC exponential approach, that profile causes no abrupt changes in dv/dt .

The power-down transient is even more problematic as these output capacitors need to be discharged to GND. How can any amplifier control the output-capacitor discharge when it has no power supply?

A Different Approach

The ideal approach would be to eliminate the output capacitors entirely, thereby negating the effect of charging or discharging through the headphone voice coils. The capacitors can be eliminated, for example, by DC-coupling the headphone drive, having a zero-volt output bias, and powering the amplifier from dual-polarity supplies. Most battery-powered designs, however, leave the designer restricted to one single-ended supply. This results in a couple of options.

One choice is to use a third amplifier to bias the headphone return to midrail, thereby creating a "pseudo-0V" output bias. Because the main stereo amplifiers are also biased at midrail, the DC coupling capacitors can be eliminated. Thus, the third amplifier must be capable of sinking and sourcing current from both of the main amplifiers and be robust enough to handle any ESD discharge from an incoming headphone jack (as the jack sleeve would now need to be isolated from the chassis).

The other option is to generate a dedicated negative supply voltage from the positive one provided, or use a headphone amplifier that conveniently generates its own negative supply (Figure 2). That latter approach makes ESD and grounding less of an issue; the extra voltage headroom allows the peak-to-peak output voltage to almost double—a useful capability when operating from a supply of +3V or less.

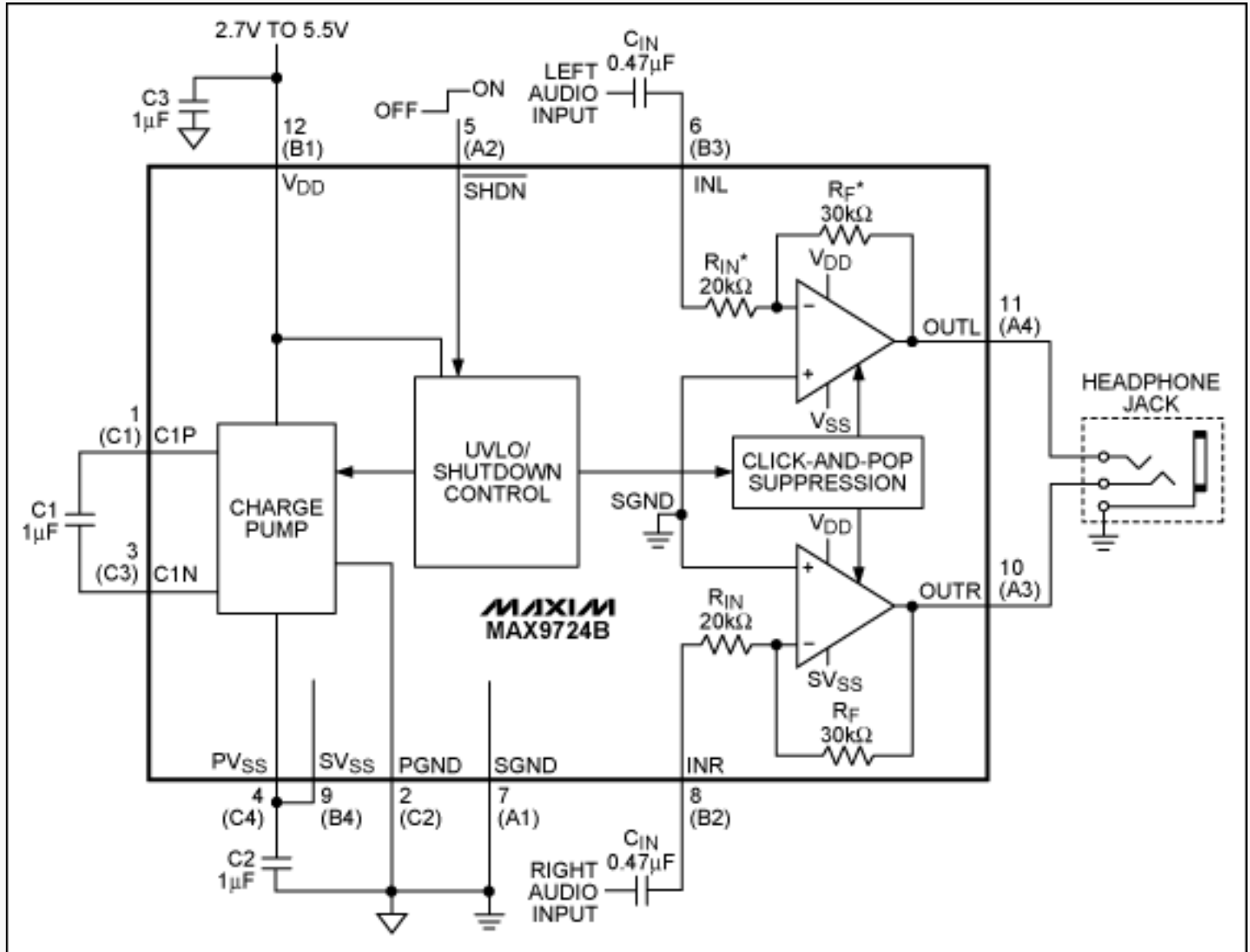


Figure 2. To allow the amplifiers to be powered from dual supplies, an on-board charge pump inverts the positive supply voltage. Series capacitors are no longer necessary, and the tiny ceramic capacitors needed for the charge pump keep PCB area to a minimum.

The MAX9724/MAX9728 headphone amplifiers generate their own internal negative supply from the positive supply pin. Output DC-blocking capacitors are unnecessary because each amplifier has a DC output bias of 0V. An internal lockout circuit prevents spurious operation caused by a supply voltage that is too low or in the process of powering up or down—hence, no pops or clicks. Because the amplifier's output-voltage swing almost doubles that of a single-supply equivalent, other benefits include more signal headroom and more output power.

Further Hurdles

A working design on the bench is usually subject to many compromises before product launch. ESD requirements, for instance, may call for ferrite beads or other EMC measures between the headphone driver and jack socket. Those components can have a significant impedance at audio frequencies, which can lead to crosstalk problems and a loss of output power. Careful design and Kelvin-sensing techniques, however, can recover good audio performance. Return currents from the headphone should be considered as well. With currents pushing 100mA, the finite impedance of a ground plane or PCB track can produce significant IR drops, leading again to reduced output power and poor channel separation. A similar mechanism degrades SNR when you share grounds with a DC-DC converter. Dedicated return tracks or copper fills can help in that regard.

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