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APPLICATION NOTE 5792

# MULTIPLEX BOOSTED CLASS-D WITHOUT ADDITIONAL EXTERNAL CIRCUITRY

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*Abstract: Boosted class-D amplifiers drive speakers with voltages greater than the supply voltage. These amplifiers are becoming more common because they allow higher performance audio from a single lithium-ion battery. Most boosted class-D amplifiers, however, do not give the user access to the internal boosted oltage. This makes it difficult to multiplex a speaker to multiple audio sources using common analog switches. This application note discusses how the Beyond-the-Rails capability of the MAX14689 allows it to switch these signals without additional circuitry.*

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## Introduction

Audio engineers increasingly use boosted class-D audio amplifiers in handheld systems due to their ability to provide high-performance audio from low-voltage sources such as single-cell lithium-ion batteries. When a cell phone is being used as a portable media player or a speakerphone, for instance, a class-AB amplifier is insufficient to provide the desired clarity and volume. A class-D amplifier is used instead. When the cell phone is used as a handset, however, the class-AB amplifier provides great performance while preserving power. The desire to preserve power in handset-like applications while still allowing big sound in speakerphone or media player applications makes it attractive to multiplex a single speaker to multiple audio sources. Difficulties arise in such applications as the boosted audio signal from the class-D amplifier often puts the audio signal outside the range of a typical analog switch. This application note discusses how the Beyond-the-Rails® capability of the MAX14689 allows it to switch such signals without additional circuitry.

## The Problem

Boosted class-D amplifiers provide big sound without requiring big space on a PCB. When multiplexing the boosted amplifier to a speaker, however, a problem arises. The audio signal output by the boosted class D is, by design, greater than the supply voltage. However, common analog switches are limited to signals within their supply rails. Many modern analog switches have added the capability to pass signals below the negative supply. This still poses a problem for the boosted signals from class-D amplifiers as signals above the positive supply are not able to be passed. The boosted supply internal to the class-D amplifier is usually not intended for use in powering external devices. Even when it is capable, the voltage is only available when the amplifier is on. This makes use of such a supply impractical since it is not available when the other amplifier is in use. It is, therefore, difficult to use typical analog switches in speaker multiplexing applications without including additional circuitry. There are several ways to address this problem, and this application note summarizes the trade-offs of each.

## Common Approaches to Solving the Problem

One solution is to increase the supply voltage provided to the analog switch. This allows the analog switch to pass the audio signal without difficulty. Another approach is shifting the audio signal levels and bringing the signal within the appropriate range for the switch. Lastly, to solve this problem, engineers can use the MAX14689 double-pole double-throw (DPDT) analog switch with Beyond-the-Rails technology. This solution allows the audio signals to pass undisturbed and with no additional external circuitry. Below is an analysis of the advantages and disadvantages of each approach.

## Increasing the Supply Voltage

In some cases, it seems advantageous to simply tap into the boosted voltage coming from the boosted class-D amplifier. As mentioned above, this solution creates a new problem: when the other amplifier is in use, the boosted class-D amplifier is turned off and the boosted voltage is not available. The designer must then devise a way to power the analog switch from another source. This means the system must be designed with additional OR circuitry powering the switch from different sources depending on which amplifier is in use. The OR circuitry required for such a solution consumes additional space and power. Such trade-offs are not desirable in systems where space and power consumption are the main design constraints.

Though uncommon, another approach to the problem is to add an external boosted power supply to the circuit using either inductive or charge pump methods. This solves the problem, but has obvious disadvantages. For one, the space-constrained nature of most modern applications makes this an unacceptable way to solve the problem. The additional boosted power supply means adding bulky external components (IC/diode/capacitor/FET/inductor). This simply will not do. Additionally, even a highly efficient boost converter introduces power losses that are unacceptable in systems operating from a battery.

## Shifting Audio Levels to Acceptable Range

Many analog switches used in audio applications support negative voltages. As a result, shifting the DC bias of the signal down until the signal falls within the acceptable voltage range for the switch is a commonly implemented solution. Most frequently, the DC blocking approach is used. In this approach, the engineer places DC-blocking capacitors at the input of the analog switch. The problem with this approach is three-fold. First, capacitors add components to an application that is already tight on space. Moreover, the capacitors that are added need to be fairly large in value so as to keep the cutoff frequency of the highpass filter they create as low as possible. Since the load at this point is the speaker rather than a higher-impedance input to the amplifier, this further increases the size of the capacitor needed to maintain audio quality.

The second issue that arises compounds the first. Capacitors added for DC blocking add phase distortions at low frequencies due to their voltage coefficient. The voltage coefficient describes how much the capacitance value changes with the voltage across the capacitor. Since at low frequencies the capacitor becomes higher impedance, a voltage develops across the capacitor thereby decreasing the capacitance below the rated value. As the frequency increases, so, too, does the capacitance. The change in capacitance introduces distortions at frequencies up to ten times higher than the -3dB point of the filter. Therefore, to keep the distortions out of the audible range, capacitors should be large enough to create a cutoff frequency as low as 2Hz. Additionally, the capacitors selected should have a low voltage coefficient, which typically excludes capacitors that are available in small packages, such as ceramics. Most commonly tantalum or electrolytic capacitors are used to keep the voltage coefficient low.

Finally, more distortions are introduced from factors such as nonlinearities in equivalent series resistance (ESR). Nonlinearities in the ESR can be frequency-dependent and in some cases limit power delivered to the speaker due to the increased impedance.

The DC-blocking approach solves the problem, but requires trade-offs in the areas of cost, audio quality, and space constraints.

## The Maxim Solution

The Maxim solution (**Figure 1**) to this problem is the MAX14689 ultra-small, double-pole, double-throw (DPDT) analog switch, which allows boosted signals to be passed without additional external circuitry. The MAX14689 features Beyond-the-Rails technology that allows signals up to ±5.5V to pass with ultra-low distortion while the device is supplied with voltages as low as +1.6V.

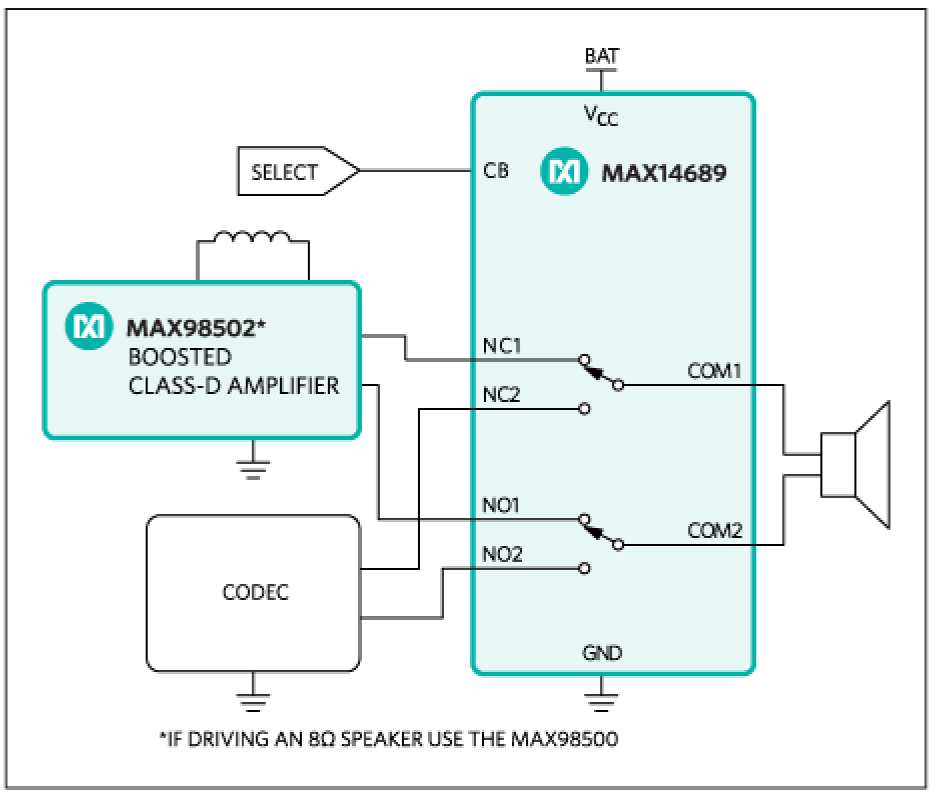


Figure 1. Solution for typical audio setup.

Given the ability of the MAX14689 to pass voltages above and below the supply rails, the need for DC blocking or a boosted external supply is eliminated. In fact, implementation of a multiplexed speaker using the MAX14689 allows the engineer to power the audio system with no additional external circuitry, saving considerable space. The ability to pass signals without DC-blocking capacitors eliminates both the space taken by and the distortions introduced by DC-blocking capacitors. The 1.2mm x 1.2mm, 9-bump wafer-level package (WLP) makes the MAX14689 the industry's smallest DPDT analog switch, which enables additional space savings.

The MAX14689 utilizes "break-before-make" timing to prevent the two amplifiers from ever being shorted together, and it protects the audio quality of the system while also reducing the space required as compared to other common solutions. When powered with a supply as low as 2.5V, the low (0.25  typical) on-resistance of the switch allows for a highly efficient transfer of power to the speaker. The low THD+N introduced by the MAX14689 makes this solution excellent for audio systems where space, cost, and audio quality are highly important.

## Conclusion

Boosted class-D amplifiers are attractive in battery-powered audio systems because they provide great increase in audio quality. Due to the higher power consumption of such amplifiers, however, it is not advantageous to have this type of system always on. Since multiplexing a single speaker to separate audio systems presents many advantages, the inability of typical analog switches to pass signals above and below their supply rails creates a problem worth solving. Traditional solutions introduce many unwanted effects, but the Maxim solution provides a simple, space-saving, and audio-quality-preserving solution.



| **Related Parts** | | |
|---|---|---|
| MAX14689 | Ultra-Small, Low-$R_{ON}$, Beyond-the-Rails DPDT Analog Switches | Free Samples |
| MAX98500 | Boosted 2.2W Class D Amplifier with Automatic Level Control | Free Samples |
| MAX98502 | Boosted 2.2W Class D Amplifier with Automatic Level Control | Free Samples |

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