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# AN-6044

## Pop Suppression Techniques Using Analog Switches

### Introduction

Consumers expect portable devices packed with more and more features to maintain excellent battery life and small form factor. One trend is the integration of multiple music functions into a single device; such as the addition of digital music players into cell phones. With this migration to all-in-

one phone/MP3 player combination, analog switches are often employed to allow multiple sources to share a single speaker or vice versa. Due to the nature of standard AC-coupled systems, there is the possibility for a “pop” noise when switching audio signals.

### Applications Sources of Pop Noise in Audio Switching Applications

Figure 1 illustrates a traditional  $V_{CC}/2$ -biased audio path with an analog switch, where an AC coupling capacitor is required to shift the audio signal bias from  $V_{CC}/2$  down to 0V prior to entering the speaker. This application is fairly common because it allows a single speaker to share multiple audio sources within the device. This figure illustrates the bias shift resulting from the audio signal passing through the AC-coupling capacitor.

A second common application (not shown) is for a single amplifier to drive multiple speakers. This is accomplished by taking advantage of the switch’s bi-directional nature. By connecting the audio source to the common port, the switch can be used to route audio signals between two output speakers, such as headphones and speakerphone outputs. Because many audio amplifiers require output signal at

$V_{CC}/2$  and standard analog switches require a positive input signal, AC-coupling capacitors are added to shift the signal bias from  $V_{CC}/2$  down to 0V before entering the speaker coil. In this application, there are several instances where noise pop can be introduced. For example, if the audio amplifier output bias is ramped up too quickly, this can result in sudden voltage changes across the capacitor. A second case is when switching between two different audio sources or in changing routing from one speaker to another by toggling the analog switch. During either of these scenarios, a sudden change in voltage differential can arise across the capacitor. In AC-coupled systems, the pop generally results from a sudden change in voltage across the capacitor.

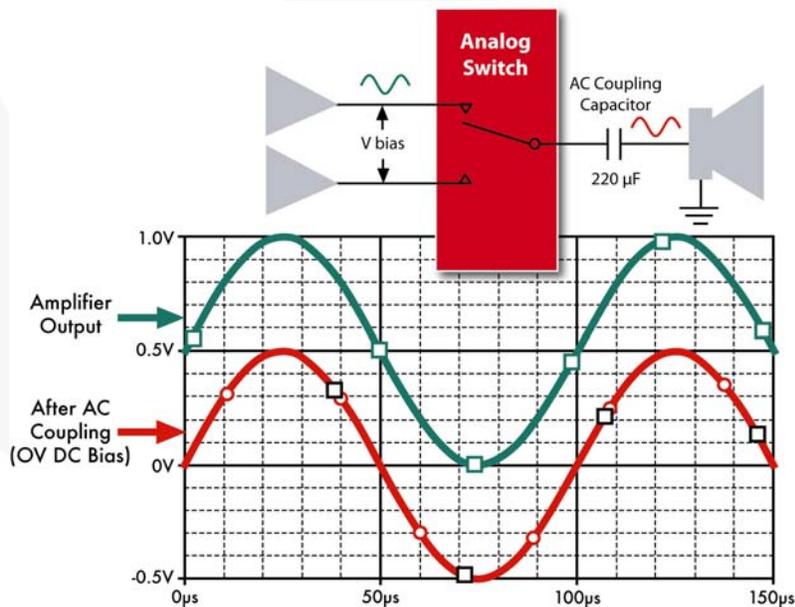


Figure 1. Standard Analog Switch (Demonstrating Bias Shift)

## How AC Coupling and Stray Capacitance Lead to Audio Pop

The audio pop noise is a result of the capacitive charge/discharge characteristic of the AC-coupling capacitor and the inductive speaker coil's response to these changes. To explain why a sudden voltage change across the AC-coupling capacitor causes pop noise, refer to the equation for current through a capacitor given by:

$$I = C \frac{dv}{dt} \quad (1)$$

This equation indicates that with sudden changes in voltage, there is a proportional increase in current through the capacitor. When audio signals are sent to speakers, the changes in voltage are a function of the maximum changes in signal amplitude relative to the frequency of the given audio signal. Because analog audio is limited to the 20Hz to 20kHz range, the relative changes in signal amplitude in proportion to the signal period are small; resulting in very little current flow through the capacitor. During steady-state operation, the amplitude driven by the amplifier varies slowly and the current flowing through the capacitor to the speaker is fairly constant. Sudden changes in voltage on either side of the capacitor (large  $dv/dt$ ) result in a proportionally large change in current through the capacitor. To understand how this impacts the speaker, look at an

equation describing the inductive response of a speaker to changes in current. Because a speaker is basically an inductive coil, the following equation is used to describe inductive behavior:

$$V = L \frac{di}{dt} \quad (2)$$

This equation states that changes in current result in proportional changes in voltage across the inductor. This voltage is a result of changes in the inductor's stored magnetic field. A speaker works like a solenoid in that changes in the magnetic field are used to push the speaker cone in and out. Changes in the current at the speaker coil (inductor) control the rate at which the speaker cone moves in and out, creating sound waves to reproduce the sound.

These two equations allow a better understanding of the causes of audible pop where there is a sudden voltage change across the AC-coupling capacitor. A sudden voltage change results in a current spike through the capacitor, which, in turn, causes the speaker coil to quickly react by pushing or pulling the speaker cone in or out as the inductor tries to compensate for a sudden change in current. This sudden movement of the speaker cone is audible to the human ear as a sharp pop noise.

## Different Approaches using Analog Switches to Minimize Audio Pop

Audio pop is the result of rapid movement in the speaker and can be induced by signal switching, system power up, or any other action which results in sudden changes in voltage on the signal line. Because capacitance is the root cause of this noise, eliminating the need for a relatively large AC coupling capacitor (typically 100-220 $\mu$ F) eliminates the primary source of audio pop. By transitioning to a negative-swing-capable audio system, the AC-coupling capacitor can be removed. In addition to using a negative-swing-capable analog switch to reduce pop, some analog switches also have features like built-in termination on un-selected outputs and slow turn-on / turn-off times during switch toggling to lessen the probability of audio pop. Following is an explanation of each of these approaches, which can be employed individually or collectively.

### Negative Swing Systems Eliminate the AC-Coupling Capacitor

With the introduction of Fairchild's negative-swing-capable analog switches, it is possible to transition to a fully functional negative-swing audio system. Figure 2 shows the same system configuration as Figure 1, using a negative-swing audio amplifier in conjunction with a negative-swing analog switch. In this application, the AC-coupling capacitor is no longer needed because the audio output from the amplifier is already biased at 0V. Because the analog switch can pass the negative input signals, there is no need to

change the amplifier output bias to prevent clipping (as would be the case in a non-negative-swing-capable switch). Removal of the AC-coupling capacitor eliminates the primary source of pop noise in audio systems by eliminating the capacitive charge/discharge effect and consequently the pop-creating current spike. It not only improves audio performance and quality, but also has the additional benefits of saving board space (coupling capacitors are typically quite large, ranging from 100-220 $\mu$ F) and simplifying the system bill of materials. These benefits result in more flexibility for the designer and total system cost savings.

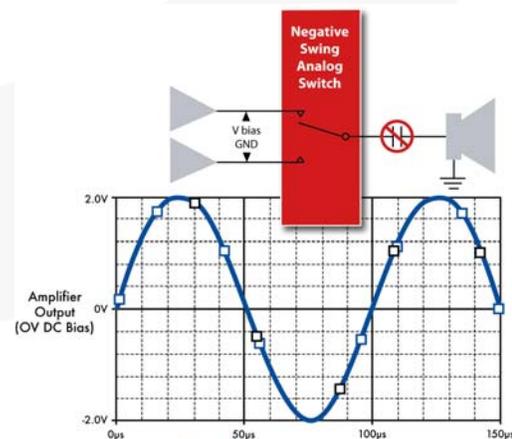


Figure 2. Negative-Swing Audio System without AC Coupling

## Terminate Unused Ports to Ground

A second method employed to reduce audio pop is the addition of termination resistors on un-selected ports. This enhances the noise suppression characteristic of the switches by ensuring that any charge build up in parasitic capacitance on unselected ports is dissipated before the line is connected to the output speaker. By removing this charge before connecting to the speaker, the switch prevents this charge from flowing to the speaker. It allows designers to coordinate the turn-on timing and amplifier output bias of the audio amplifiers based on the known switch port bias point. In the case where a single amplifier is driving multiple speakers, it ensures that the un-selected speaker output is held at ground so there is no sudden voltage change in the audio path when the switch is toggled.

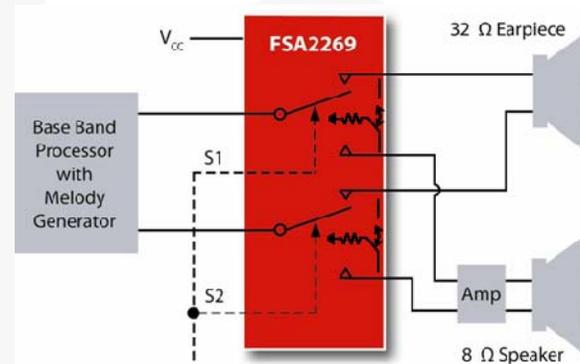
## Control Switch Turn-On Edge Rate

A third approach to minimizing audio pop is to intentionally slow down the switch turn on time by slowing down the output edge rate. Slowing the switch turn-on time allows the switch to connect input to output port in a controlled manner such that it reduces the effective  $dv/dt$  seen by any line capacitance; whether it be AC coupling or parasitic board capacitance. By stretching out the 'dt' portion of the  $dv/dt$  relationship, the change in current seen by the speaker ( $di/dt$ ) is also minimized, helping reduce the probability of audible speaker pop.

## Simultaneously Use All Three Techniques

The most effective approach is to combine all three techniques. Some analog switches, like the FSA2269T, simultaneously employ all three techniques to maximize audio pop reduction. In addition to passing a negative signal, these analog switches have built-in termination resistors on the unselected ports, as well as a slow turn-on feature. Built-

in termination and slow turn-on might seem unnecessary for a negative-swing system where the AC-coupling capacitor is no longer an issue; but the AC-coupling capacitors are not the only source of capacitance. Removal of the AC coupling only eliminates the primary source of line capacitance. In every system, there is also always some stray capacitance on the signal line. This extra capacitance results from inherent board parasitics, as well as input and output capacitance of components in the audio path. Although these are small compared to the AC-coupling capacitors, they can result in noise coupling to the speakers. The second and third methods for mitigating audio pop address the pop that can occur from these secondary sources of line capacitance in a negative-swing system. Figure 3 shows a schematic using the FSA2269T with all three techniques employed.



**Figure 3. FSA2269T Negative-Swing-Capable Switch with Built-In Termination**

Adding termination resistors and a slow turn-on feature to the negative-swing-capable switch further enhances the effectiveness of pop noise suppression. Because all three features operate independently, it also allows this type of product to be used in traditional AC-coupled systems with less chance of audible pop than would be likely using a traditional analog switch.

## Conclusion

Negative-swing-capable analog switches with built-in termination and slow turn-on are enabling the use of negative-swing amplifiers in portable designs. This capability allows designers to remove AC-coupling capacitors, while significantly reducing audio pop and improving the end user experience. Built-in termination and slow turn-on further enhance the pop suppression performance. These new products are yielding improvements in total system performance, helping to reduce part count, and saving board space. They also are very efficient, using no more power than existing analog switches, which translates to improved audio performance and longer battery life.

## Related Datasheets

FSA2268 / FSA2268T

FSA2269 / FSA2269T

FSA221

FSA201

FSA203

FSA2380

FSA2367

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