TI Audio's New High Efficiency AD Modulation Scheme for Class-D Amplifiers

Avi Yashar, Audio Amplifier Products

Battery-operated portable Bluetooth and Wi-Fi speakers have grown in popularity around the world. Designers are often cost and space-restricted for battery capacity. Hence, an efficient amplifier is paramount to maximizing battery life. To further improve efficiency in Class-D amplifiers, TI developed a proprietary modulation scheme first implemented in the high-power TPA3221 Class-D amplifier, called High Efficiency AD modulation (HEAD). HEAD modulation differentiates itself with benefits such as reduced idle power losses, improved EMI performance, and even less pop noise than AD modulation. This makes TPA3221 an ideal choice for wireless speakers and other applications where efficiency, system size and cost are critical. This Tech Note elaborates on how HEAD Modulation produces differential output for a bridge-tied-load (BTL) system shown in Figure 1, and the mechanisms behind the benefits mentioned above.

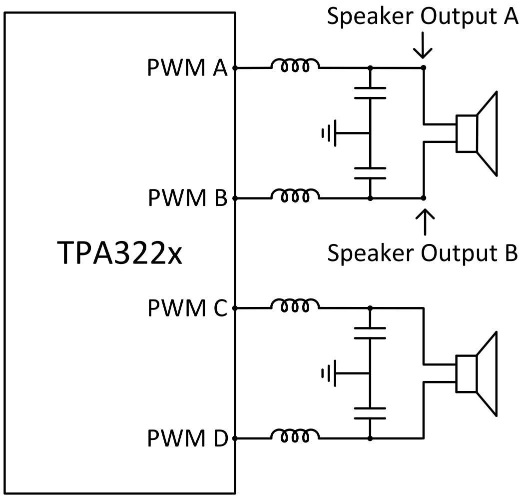

Figure 1. BTL Output Configuration

In BTL, the audio signals leave the amplifier as a pair of PWM signals (PWM A and B). They then filter through LC networks, becoming analog signals (Speaker Output A and B). These outputs result in a differential signal across the speaker. To understand the TPA3221's high efficiency modulation scheme, let's start with the idle state (no audio signal). Figure 2 shows different levels of an audio signal. Figure 3 and Figure 4 show AD and HEAD modulation across the signal chain with different level audio signals. The figures are color coordinated, red representing the idle state.

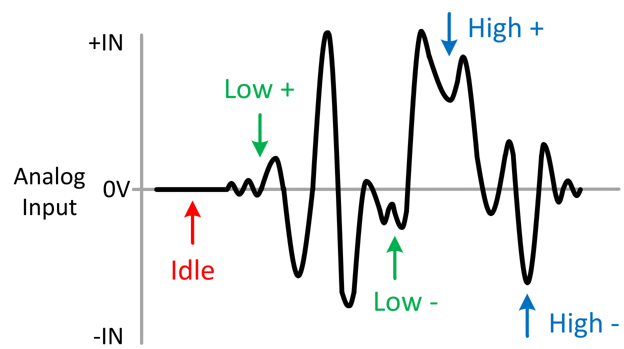

Figure 2. Analog Audio Signal

AD Modulation achieves idle (0V seen by speaker) with 50% duty cycle at PWM A and B, resulting in +½ PVDD at Speaker Output A and+½ PVDD at Speaker Output B after the LC filter. The speaker sees the voltage at A minus the voltage at B and therefore, experiences zero volts. HEAD differs by using two lower duty cycle signals for idle instead of 50%. This results in a less-than-half-PVDD at Speaker Output A and Speaker Output B, but since they are still equal, the differential across the speaker is also zero volts.

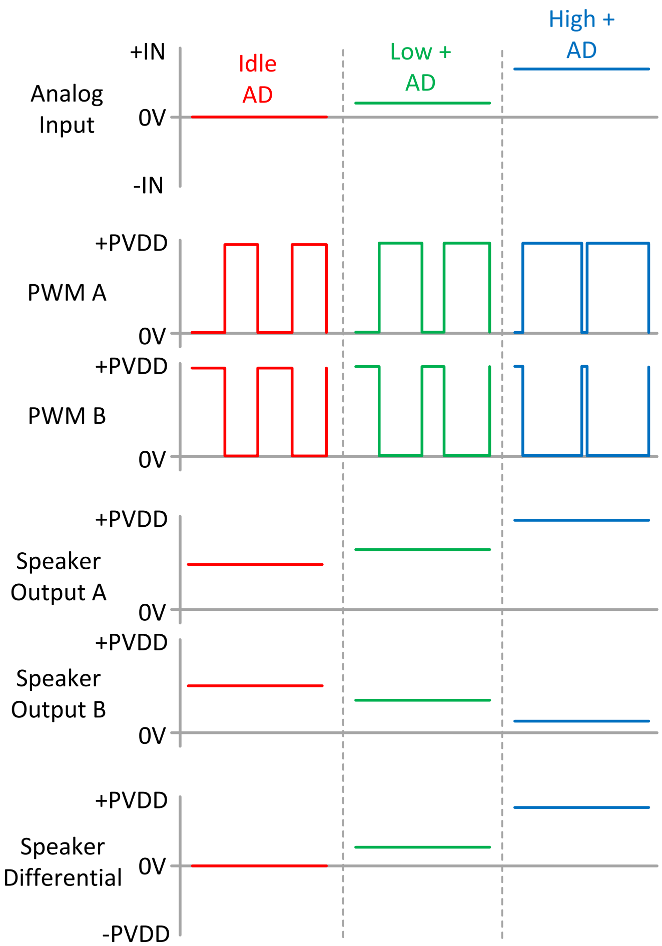

Figure 3. AD Modulation

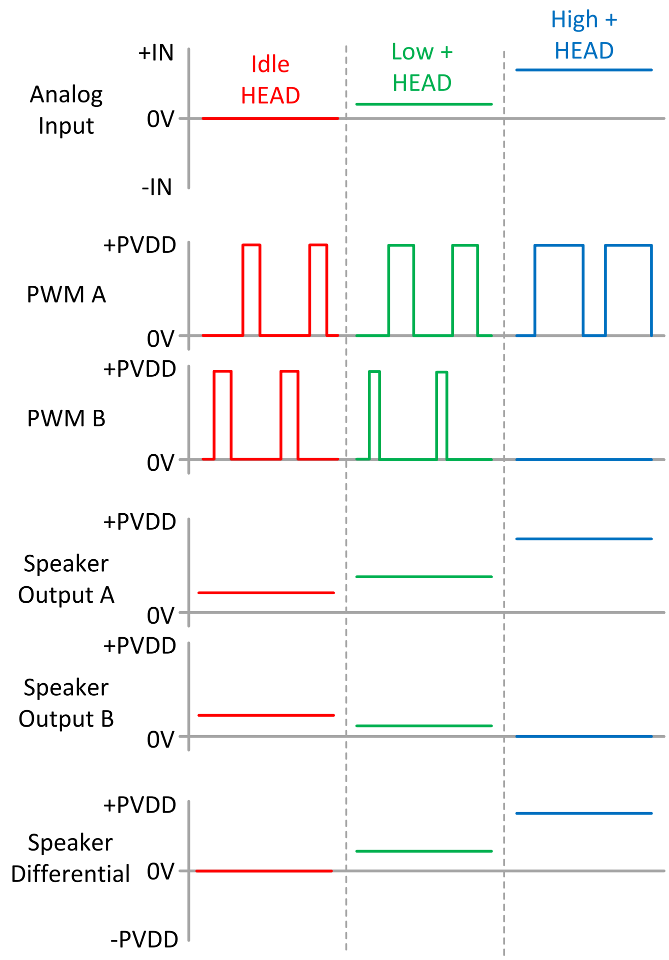

Figure 4. HEAD Modulation

In AD and HEAD modulation, a low-magnitude differential output is generated by increasing the duty cycle of one PWM signal and decreasing the other one relative to idle. In Figure 3 and Figure 4, the duty cycle of PWM A is increased and PWM B is decreased to create a positive differential. For AD, PWM A and B always change at a rate equal in magnitude and opposite in direction, from idle all the way to max output. In HEAD, since the idle state is defined at a lower duty cycle than 50%, as PWM A increases PWM B reaches 0% duty cycle before the max differential output is achieved across the speaker. Above this threshold in HEAD, PWM A increases its duty cycle at twice the prior rate, since PWM B cannot decrease further than zero to contribute to the differential output.

TI engineers carefully optimized the duty cycle for the HEAD modulation idle state. An adequately low duty cycle for the idle state results in lower idle power losses and improved EMI performance. Too low of a duty cycle would result in poor performance and a loss of these benefits.

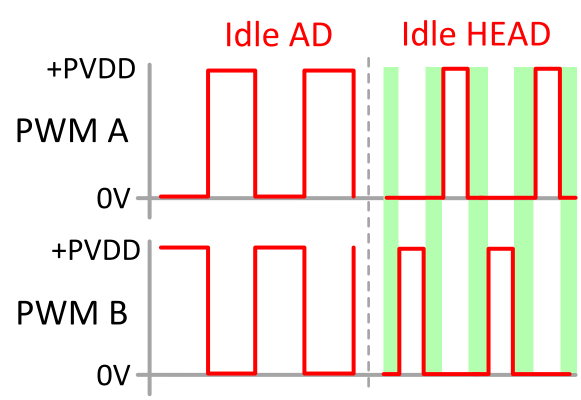

Figure 5. AD and HEAD Idle PWM

Visualized in Figure 5, the HEAD idle state has periods where both PWM A and PWM B are at 0V. The lower duty cycle reduces the RMS current, as the peak-to-peak current is proportional to the duty cycle. Consequently, both conduction losses due to ripple current through RDSON and switching losses are reduced. Figure 6 shows the improvement of HEAD idle current compared to AD idle current for the TPA3221 amplifier in BTL.

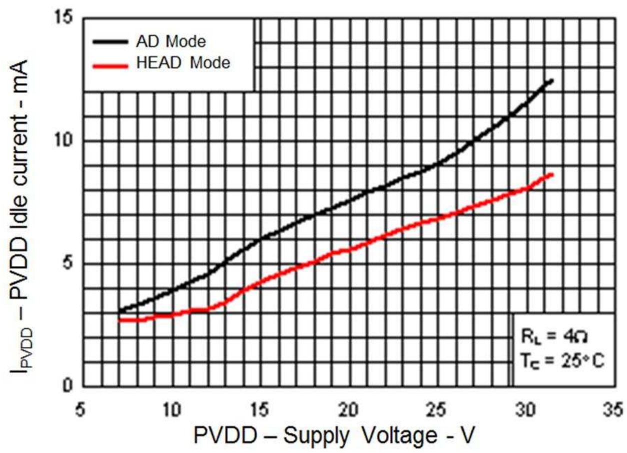

Figure 6. HEAD and AD Idle Current in BTL

The narrower pulses also benefit EMI performance due to their reduced spectral content, emitting a significantly lower magnitude of high frequency energy. Lastly, since the idle duty cycle is lower in HEAD than AD, the pop sound generated by ramping up to and down from idle in HEAD is a small fraction of that in AD.

The improvements of HEAD make it a highly desirable modulation scheme for battery-powered speakers and other applications concerned with efficiency, EMI, or pop noise. As the world continues to demand louder, better-sounding, high-resolution Bluetooth and wireless speakers with longer battery life, TI Audio provides innovative solutions to take your products to the next level.