Application Report

SLAA836 – May 2018

Minimize Idle Current in Portable Audio With TAS5805M Hybrid Mode

Shawn Zheng, Peter Cao

ABSTRACT

The Class-D audio amplifier is an important piece of the portable audio design, and is confronted with many challenges such as smaller form factors, lower power, and higher performance. To achieve low power losses, multiple factors must be taken into consideration, including the PWM switching frequency, the inductors in the output LC filter, and the modulation mode of the amplifier. This application note explains and compares how each factor affects the idle current using the TAS5805M, which features the ultra-low-idle-current Hybrid Mode Modulation.

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1 General Overview

The low idle current helps to extend the battery life and reduce the power consumption in consumer electronics. To achieve lower idle current, the TAS5805M supports different LC filter configurations, PWM frequency and modulation mode configurations.

2 Ripple Current on the Inductors

Ripple current on the inductors is defined as the alternating current flowing through the output inductor of a class-D amplifier. The ripple current contributes the most to the total idle current. Lower ripple current on the inductors makes lower idle current. This application report analyzes the ripple current in idle state.

Figure 1 shows that when in BD modulation mode, class-D amplifiers produce a common-mode voltage of PVDD/2 after the LC filter at idle, which is the average value of the 50% duty-cycle PWM switching waveform.

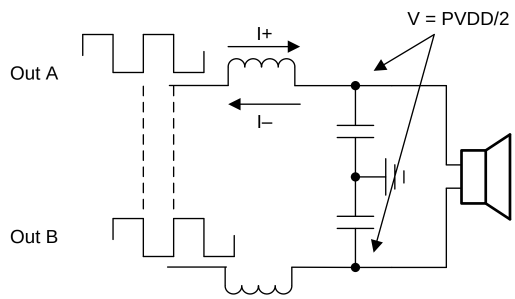

Figure 1. PVDD/2 Common-Mode Voltage

Therefore, the voltage across the output inductor changes the polarity when the PWM voltage reaches PVDD/2. The maximum voltage across the inductor is PVDD/2 and the minimum voltage is –PVDD/2 (see Figure 2).

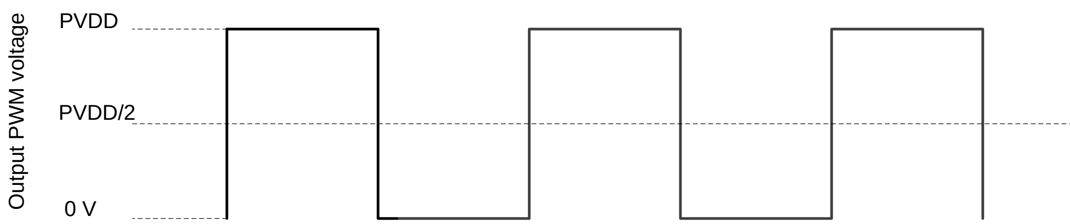

Figure 2. PWM Voltage Waveform

Figure 3 shows the inductor voltage and current waveforms drawn using these arguments.

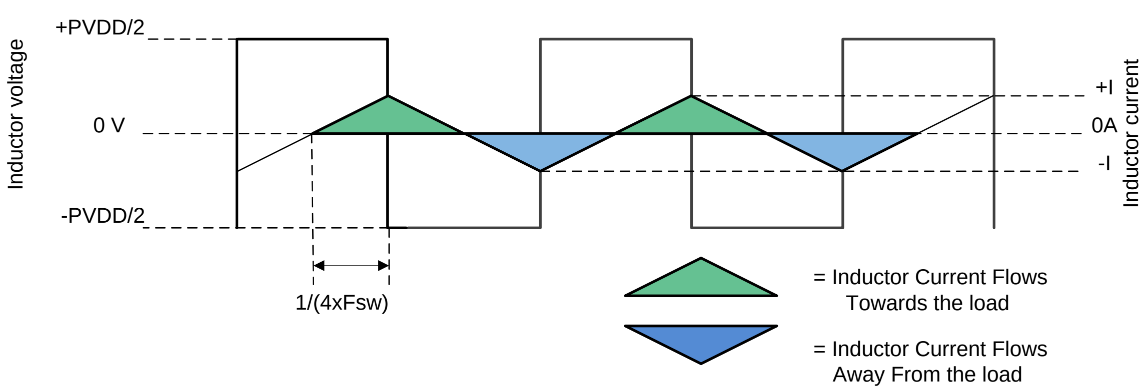

Figure 3. Inductor Voltage and Current

At idle, the positive and negative current flow through the inductor must be symmetrical and therefore centered around zero. Otherwise, there is a DC offset across the speaker and a constant average current flow through the load. The shaded regions in Figure 3 indicate the direction of current flow.

Calculate the peak ripple current at idle with Equation 2:

$$I_{ripple,peak} = \frac{\frac{PVDD}{2}}{L}\delta t$$

$$I_{ripple,peak} = \frac{PVDD}{2 \times L} \times \frac{1}{4 \times F_{SW}} \quad (1)$$

$$I_{ripple,peak} = \frac{PVDD}{8 \times L \times F_{SW}}$$

where

- L = inductor value
- F_{SW} = PWM switching frequency (2)

3 LC Filter Configuration

Equation 2 shows that the larger value inductors in the output filter make lower ripple current in idle state. Figure 4 shows the idle current with three different LC filter configurations (22 µH, 15 µH, and 10 µH) for F_{SW} = 384 kHz and Hybrid mode. Figure 5 shows the idle current with 4.7-µH and 10-µH inductors for F_{SW} = 768 kHz and BD mode.

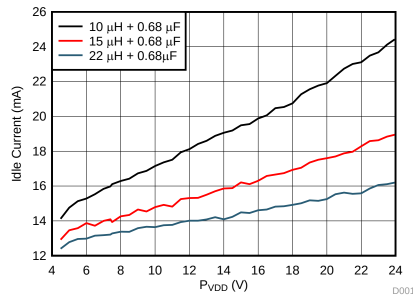

Figure 4. Idle Current vs PVDD on TAS5805M (F_{SW} = 384 kHz, Hybrid Mode)

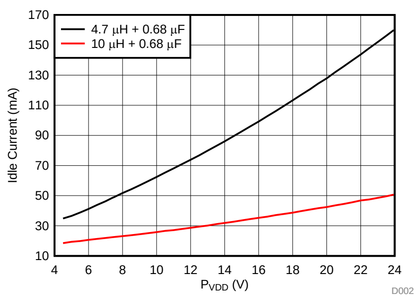

Figure 5. Idle Current vs PVDD on TAS5805M (F_{SW} = 768 kHz, BD Mode)

4 PWM Frequency

Equation 2 shows that the idle current is lower with higher PWM frequency. Figure 6 shows the idle current measurement for F_{SW} = 384 kHz and 768 kHz (10-µH inductor and BD mode).

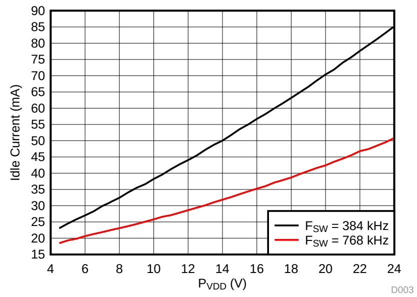

Figure 6. Idle Current vs PVDD on TAS5805M (10 µH + 0.68 µF LC Filter, BD Mode)

5 Modulation Mode

The TAS5805M device supports BD mode, 1SPW mode, and Hybrid mode. The duty-cycle is lower in 1SPW mode and Hybrid mode than it is in BD mode.

Using 15% duty-cycle as an example, the common-mode voltage after the LC filter is 0.15 × PVDD, as Figure 7 shows. The maximum voltage across the inductor is 0.85 × PVDD and the minimum voltage is –0.15 × PVDD, as Figure 8 shows.

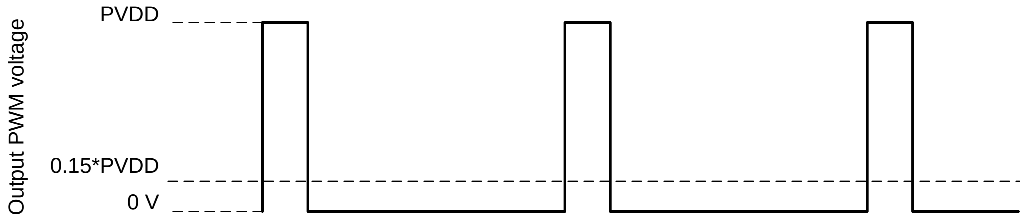

Figure 7. PWM Voltage Waveform (15% Duty-Cycle)

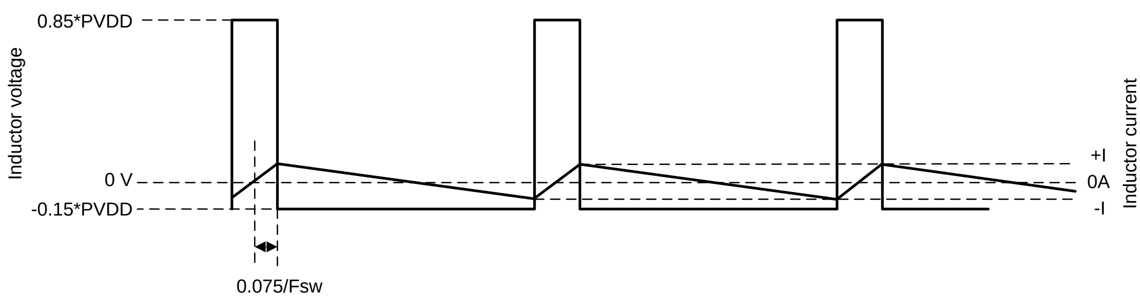

Figure 8. Inductor Voltage and Current (15% Duty-Cycle)

Apparently, the idle current is lower with the lower duty-cycle (< 50%). Figure 9, Figure 10, and Figure 11 compare the idle current between BD mode, 1SPW mode, and Hybrid mode, under different PWM switching frequencies and LC filter configurations.

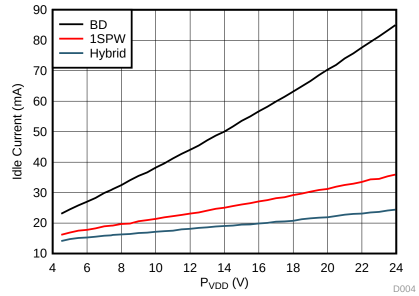

Figure 9. Idle Current vs PVDD on TAS5805M (F_{SW} = 384 kHz, 10 µH + 0.68 µF LC Filter)

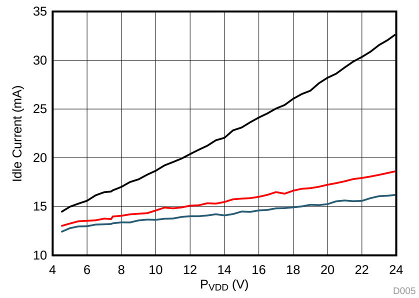

Figure 10. Idle Current vs PVDD on TAS5805M (F_{SW} = 384 kHz, 22 µH + 0.68 µF LC Filter)

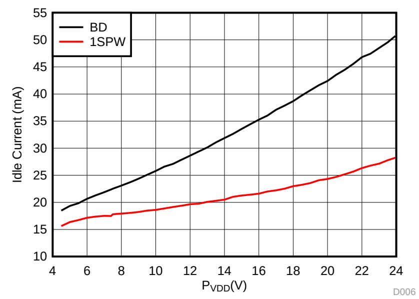

Figure 11. Idle Current vs PVDD on TAS5805M (F_{SW} = 768 kHz, 10 µH + 0.68 µF LC Filter)

6 THD Performance Measurement

THD performance is measured for 1- and 5-W output power with 12-V PVDD, 6-Ω load, and a 10-µH inductor, as Figure 12 and Figure 13 show.

The THD performance in Hybrid mode is close to BD mode. While in 1SPW mode, the THD performance is slightly worse than BD mode or Hybrid mode. The blue (cyan) curve is for 1-W output power in 1SPW mode, the green curve is for 1-W output power in BD mode, and the red one is 1 W in Hybrid mode.

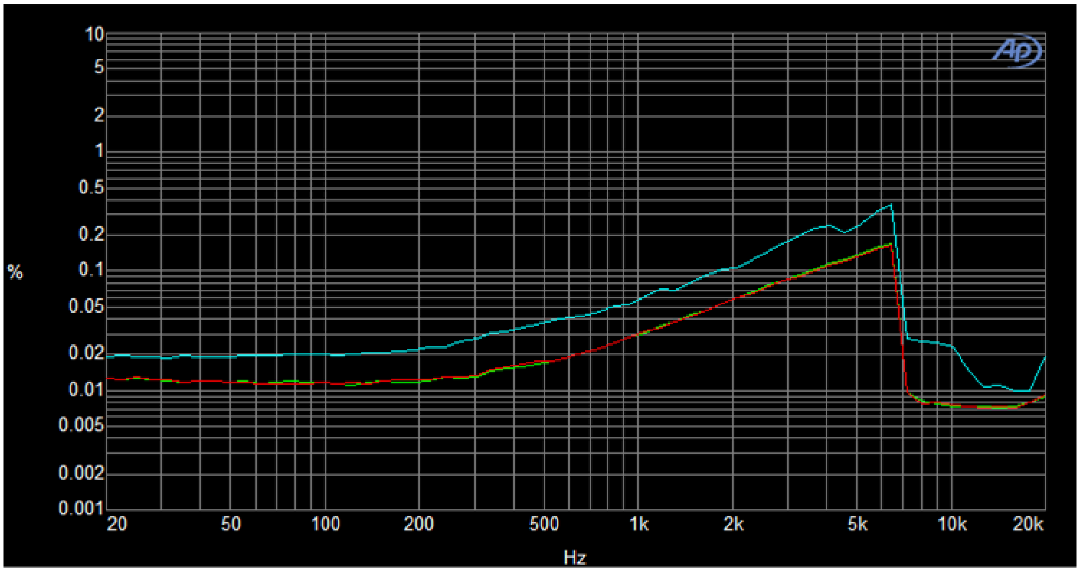

Figure 12. THD vs Input Frequency (PVDD = 12 V, Load = 6 Ω, 10 µH + 0.68 µF, 1-W Output Power)

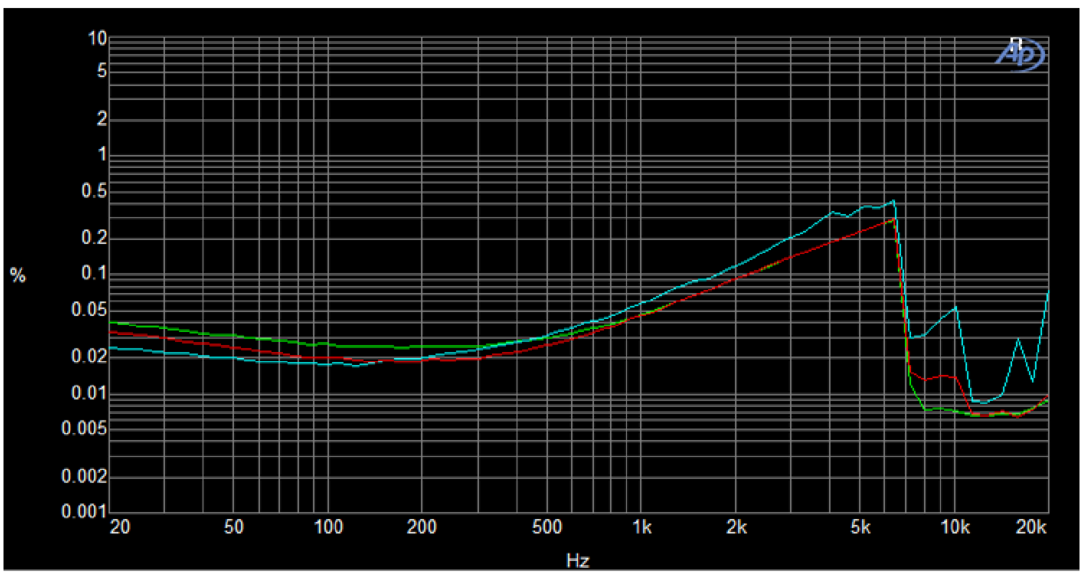

Figure 13. THD vs Input Frequency (PVDD = 12 V, Load = 6 Ω, 10 µH + 0.68 µF, 5-W Output Power)

7 Conclusion

The ripple current on the inductor depends on the output filter configuration, PWM switching frequency, and modulation mode. Very low idle current can be achieved with the TAS5805M Hybrid Mode, while maintaining excellent THD performance.

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