Application Note

Advanced Battery Guard Algorithm for Smart Amplifiers

Abstract

This application note describes the operation and features of the Advanced Battery Guard (ABG) algorithm used in conjunction with the TAS257x family of Audio Amplifiers, to monitor the battery state, and drive the speaker with the appropriate audio power.

Table of Contents

1 Introduction 2
2 Voltage Limiter Based Battery Guard 3
3 Advanced Battery Guard 4
3.1 Tracking of ESR 5
3.2 Speaker Load Tracking 5
3.3 Effect of Decoupling Capacitor 6
4 Summary 7
5 References 7
6 Revision History 8

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1 Introduction

Battery-operated systems (like mobile phones) required a boosted audio amplifier to be able to drive high peak voltage (power) into the speaker. In such systems, the battery voltage sees a ripple whose amplitude depends upon:

- Battery internal resistance
- External parasitic resistance
- Decoupling capacitance

The combination of the battery internal resistance and external parasitic resistance is represented as External Series Resistance (ESR) of the system.

When the current drawn is too high, the drop in battery voltage increases to an extent that can cause clipping of the audio. The clipping can also result in the battery voltage dropping below the brownout threshold. Figure 1-1 shows a typical battery-powered audio system, and Figure 1-2 shows the corresponding drop seen in the battery voltage due to high current.

When the current drawn is too less, there is no clipping in the audio, however there can be higher headroom between the available, where the device can be capable of driving higher power into the speaker that what is being driven.

Thus, the requirement is to regulate the current drawn from the battery to maximize the loudness of the audio while preventing clipping at the same time.

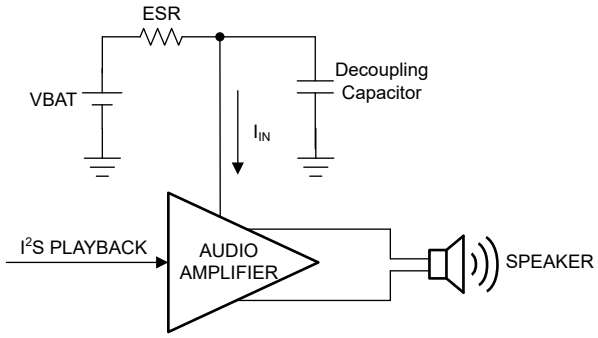


Figure 1-1. Representation of a Battery-Powered Audio Amplifier

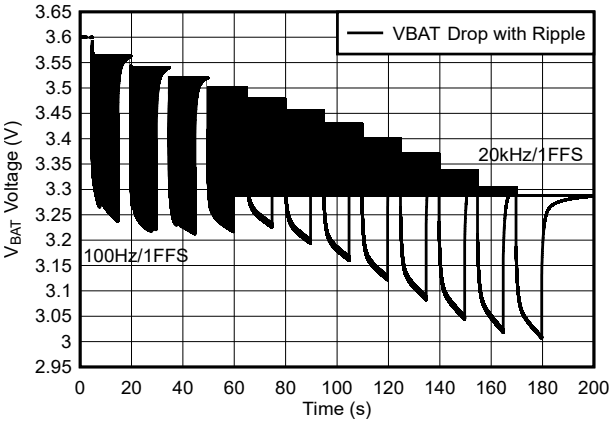


Figure 1-2. VBAT Profile During Audio Playback

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2 Voltage Limiter Based Battery Guard

The voltage limiter implementation of battery guard is based on limiting the absolute peak voltage of the amplifier to a specific level.

Figure 2-1 describes the operation of a voltage limiter. At the higher battery voltages, the peak output is limited to a fixed voltage. As the battery drops below an inflection point, the voltage driven by the amplifier also drops linearly according to a programmed slope.

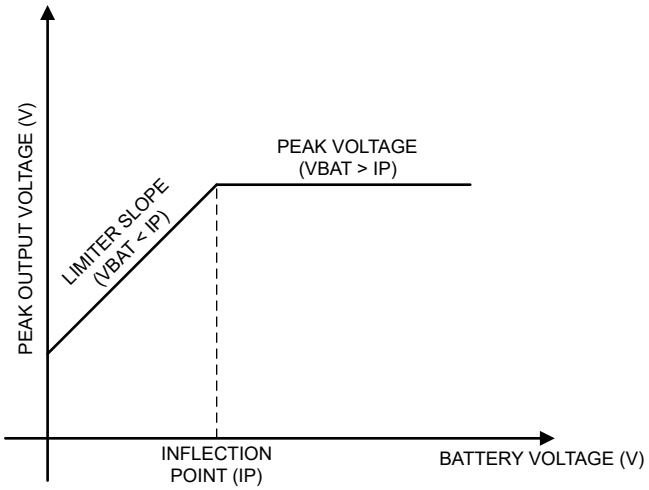


Figure 2-1. Voltage Limiter Based Battery Guard

While this voltage limiter can drive the amplifier without clipping the audio, the algorithm does not take into account the ripple on the battery voltage, and the contributions of the ESR and decoupling capacitance to the same. Also, since the output is limited to a fixed voltage, the change in speaker impedance is not accounted for either, leading to a conservative power drive.

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3 Advanced Battery Guard

Figure 3-1 represents the block diagram representation of the Advanced Battery Guard algorithm. The ABG algorithm regulates the output current drawn from the battery by limiting the output power to the speaker. The current regulation is based on:

- Estimation of the true battery voltage by monitoring the VBAT input
- Estimated ESR from VBAT ripple
- Signal frequency, where behavior is modeled based on the decoupling capacitor.

With the regulation of the audio based on the aforementioned parameters, the ABG algorithm provides increased loudness and dynamic range on the output audio. At the same time, the algorithm also regulates the output power to avoid clipping on the speaker that is being driven, while keeping the battery above the brownout voltage. The VBAT profile with and without ABG algorithm enabled is compared in Figure 3-1.

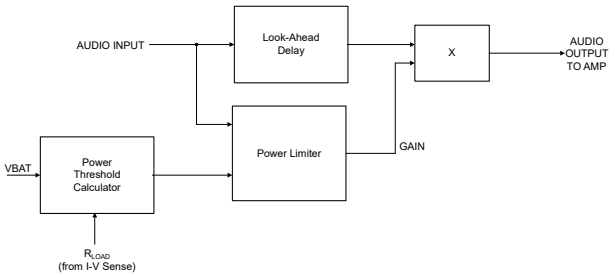


Figure 3-1. ABG Algorithm

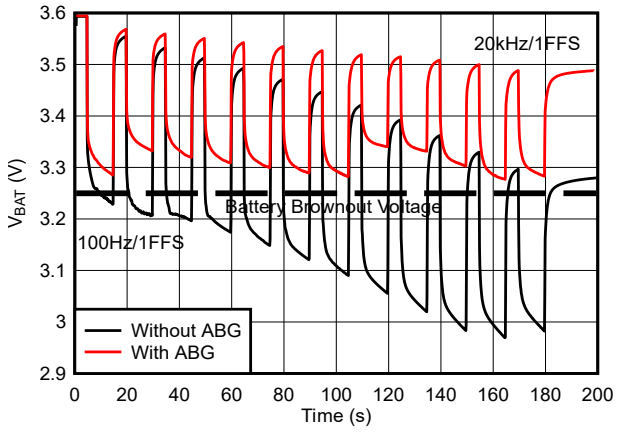


Figure 3-2. VBAT Drop Profile with ABG Enabled

The next sections describe the features of the ABG algorithm, and the results were tested using the TAS257x Stereo EVM, with a 1S Lithium-Polymer battery at 10% charge (around 3.6V), and the input audio used being a 1FFS sinusoidal tone at frequencies ranging from 100Hz to 20kHz. The setup is represented in Figure 3-3, and the test signal in Figure 3-4.

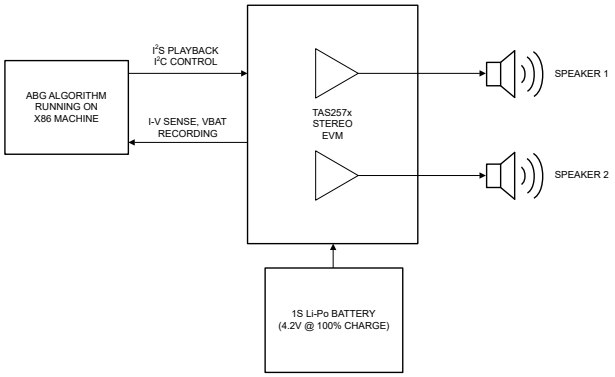


Figure 3-3. ABG Test Setup

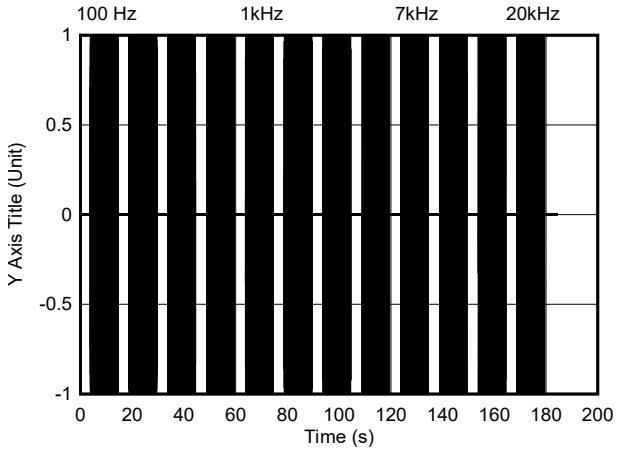


Figure 3-4. ABG Test Signal

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3.1 Tracking of ESR

The ESR represented in Figure 1-1 is a programmable input parameter for the ABG algorithm. However, when the ESR programmed is lower than the system value, the voltage can drop below the threshold. The ABG immediately corrects the current limit and tracks the ESR to keep the voltage above the brownout threshold.

When the VBAT initially drops below the battery's brownout threshold, the ABG algorithm corrects the ESR (and the output voltage) to maintain the VBAT above the threshold.

The ESR tracking by the algorithm when the actual system ESR (94mΩ) is programmed into the algorithm, and when a lower ESR (70mΩ) is programmed, along with the corresponding peak voltage profiles, shown in Figure 3-5 and Figure 3-6 respectively.

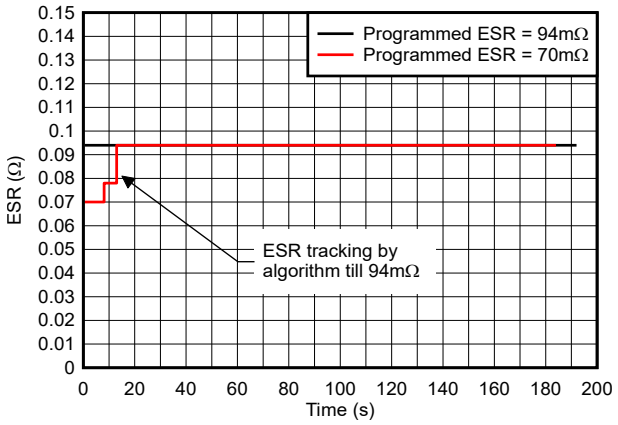


Figure 3-5. ESR Tracking by the ABG

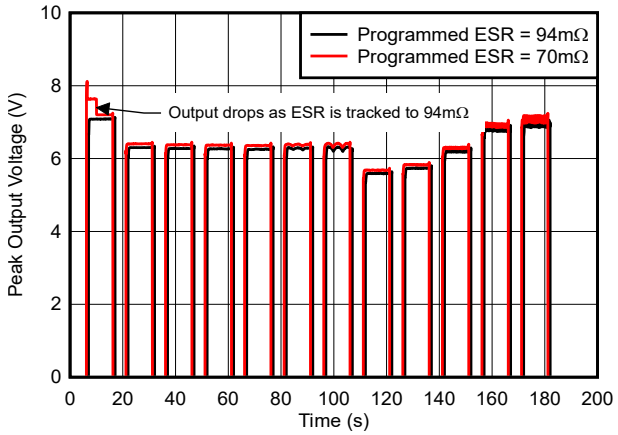


Figure 3-6. Impact of ESR Tracking on Output

3.2 Speaker Load Tracking

The ABG algorithm limits the peak power based on the battery voltage and the current limit regulated from the ESR. The speakers in the end system have variable impedance, based on temperature and tolerance. Hence, for a higher impedance speaker, the peak voltage driven can be higher compared to a lower impedance speaker, for the same output power. The speaker impedance is determined by the I-V sense data provided by the TAS257x amplifier.

Figure 3-7 shows the variation in the peak for a sine tone, when the speaker impedance is 4Ω or 8Ω. Figure 3-8 shows the difference in the peak voltages when a dynamic music track is being played across the speakers.

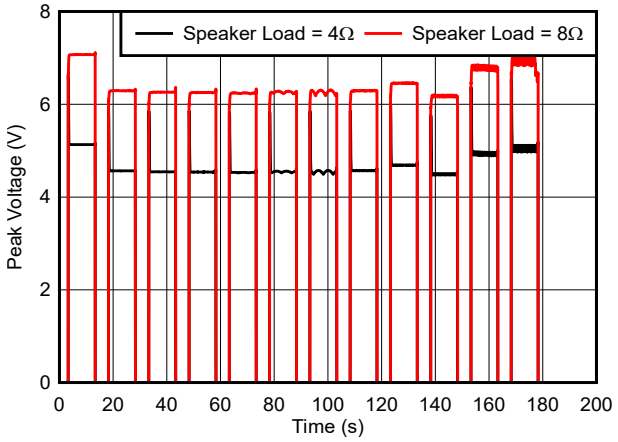


Figure 3-7. Vout Changing With Speaker Impedance - Sine Tone (100Hz-20kHz)

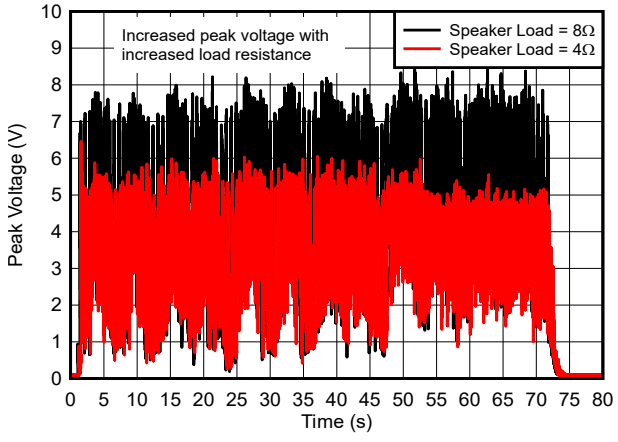


Figure 3-8. Vout Changing with Speaker Impedance - Dynamic Audio Track

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3.3 Effect of Decoupling Capacitor

The decoupling capacitor on the VBAT supply is able to supply additional power to the load specially at higher signal frequency where the duration of peak voltage is less. This reduces the VBAT ripple at high frequency. The ABG algorithm automatically adapts to the effect of the decoupling capacitor and drives higher voltage as the signal frequency increases. The ABG algorithm enables the end user to auto-tune the algorithm by characterizing the system for the decoupling capacitor used on the target platform.

Figure 3-9 shows how the ABG algorithm is able to release higher peak voltage at higher signal frequency, and Figure 3-10 shows the difference in peak output power, between a system which has been auto-tuned for a 10uF decoupling capacitor and another one for a 57uF decoupling capacitor.

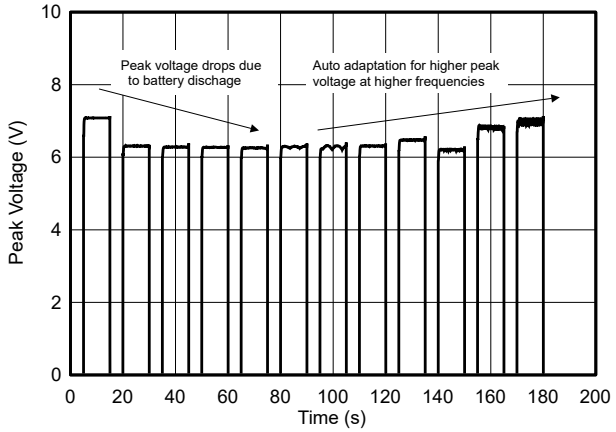


Figure 3-9. Output Increasing due to Auto Adaptation at Higher Frequencies

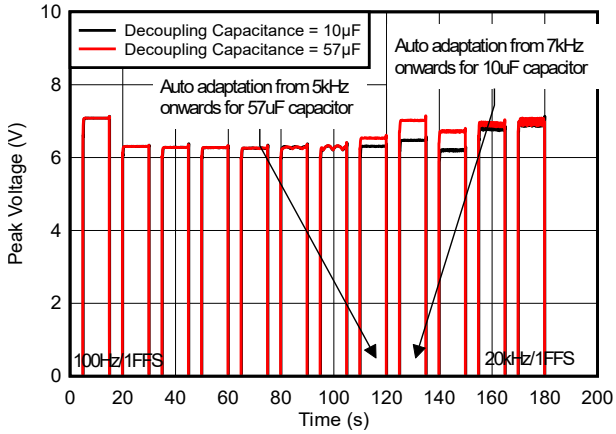


Figure 3-10. Effect of Decoupling Capacitor on Driving Peak Voltage at Higher Frequencies

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4 Summary

Table 4-1 summarizes the features of ABG algorithm, compared to the voltage limiter based battery protection.

Table 4-1. ABG Algorithm

	Limiter	ABG
Limits voltage output to protect battery	Yes	Yes
Limiter based on	Peak voltage	Peak power
ESR Tracking	No	Yes
Load Tracking	No	Yes
Auto adaptation based on decoupling capacitor	No	Yes

5 References

- Texas Instruments, *TAS2572 6.6 With Digital Input Smart Amp With I/V Sense and Integrated 13V Class-H Boost*, data sheet.

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6 Revision History

Changes from Revision * (June 2024) to Revision A (November 2026)	Page
• First public release of the document	2
• Updated the numbering format for tables, figures, and cross-references throughout the document	2

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