

Benefits of Class-G and Class-H Boost in Audio Amplifiers

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ABSTRACT

Internally boosted Class-D audio amplifiers such as the TAS2562 offer extended output power as well as efficiency gains over designs that implement a fixed boost. The Class-G and Class-H modes improve overall efficiency which ultimately extend operating battery life. In addition to extending battery life, these modes improve the overall user experience in portable personal electronics by increasing the available output power.

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1 Introduction

Class-D amplifiers convert an input signal into a series of output pulses that switch between GND and supply voltages. This PWM output is the result of modulating the input signal with the duty cycle of the output pulses. The output stage of this type of amplifier can be implemented easily using a half H-bridge architecture for each output terminal.

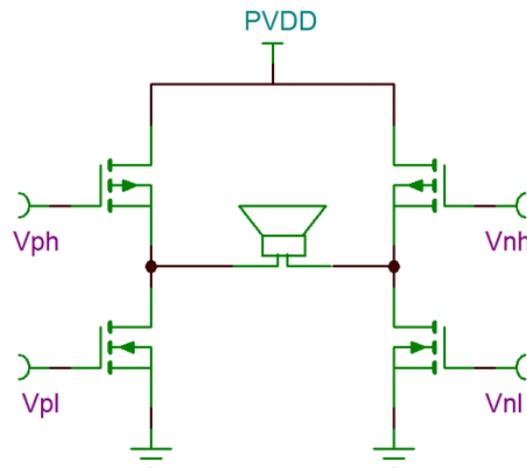
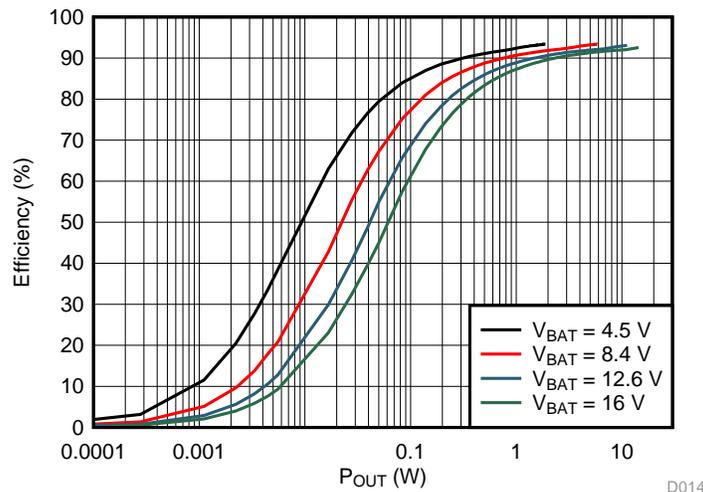


Figure 1. H-Bridge

Internal power losses are minimized by never simultaneously turning on both high-side and low-side transistors which provides a significant boost to overall system efficiency compared to Class – A, Class - B, and Class - AB amplifiers. Often, this output switching may occur anywhere from hundreds of kHz to a few MHz. Driving this modulated signal through a low pass filter will remove the higher frequency content related to the output switching and will pass only the desired signal content to the load. Class-D amplifiers are ideal in audio applications given the relatively low frequency passband needed. This makes it easy to separate the audio signal from the output switching with very low distortion. Many modern audio Class-D amplifiers can utilize the inductance of the speaker coil itself to resolve the output waveform and allow the amp to operate without any external filtering between the output and the load. However, emissions standards often require that some EMI filtering be used to limit radiated noise.

TAS2770 output efficiency is pictured below to demonstrate the output efficiency attainable using a class-D amplifier.



RL = 8Ω , Fin = 1 kHz

Figure 2. TAS2770 Efficiency vs. Output Power

Note that as output power increases there is a dramatic rise in overall output efficiency. In addition, increases to the supply voltage, V_{BAT}, shift this curve to the right. The efficiency of the amplifier depends on how closely the outputs are being driven to the supply rail. We can observe a loss in output efficiency when driving a fixed output power with higher supply voltages.

In many personal electronic applications, it is also necessary to operate the system off of a battery voltage. It is common to see operating battery voltages of handheld devices range from 3.7 V to 4.2 V. Even when operating at full scale output, there will be obvious output power limitations when the Class-D output is powered at this voltage. To increase the available output power, it is possible to configure the output stage to operate off of an additional power rail at a higher voltage. This can be easily achieved by integrating a DC-DC boost alongside the amplifier.

Consider, however, the implications this new supply voltage will have on efficiency. As mentioned above, we will expect to see a drop in overall output efficiency when driving a fixed output power with the higher supply voltage. TAS2562 is a Class-D amplifier designed to operate using battery voltages in the range of 2.7 - 5.5 V. It also includes an integrated boost. We can set this boost to always be on and measure total efficiency as shown below.

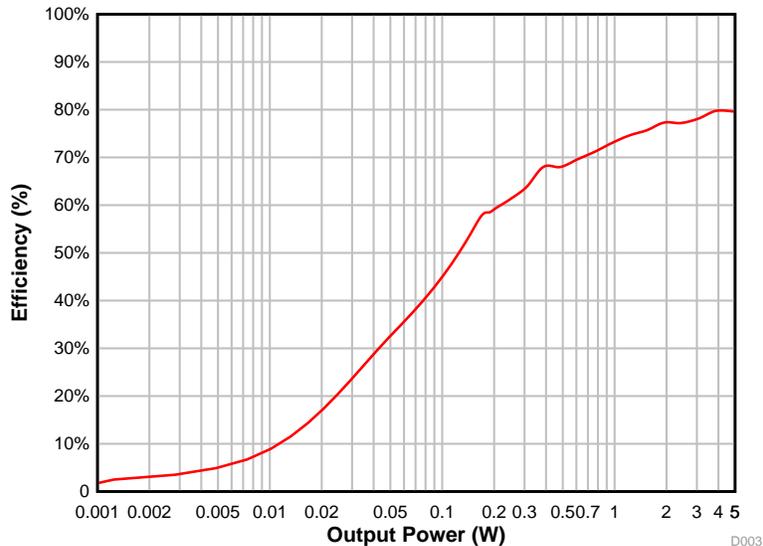


Figure 3. TAS2562 Fixed Boost Efficiency, 100 Hz

We can see that the amplifier has a peak efficiency of about 80% at the full scale output power of 5 W.

1.1 Class-G Boosted Amplifier

Class-G amplifiers help to overcome the limitation of efficiency loss with respect to supply voltage. In a class-G system, the supply voltage for the class-D output is only boosted when needed. This is easily implemented in digital input amplifiers. The device is able to monitor the input stream and determine the relative output voltages that will be driven. If the output exceeds a certain threshold then the boost will be enabled on and provide additional headroom.

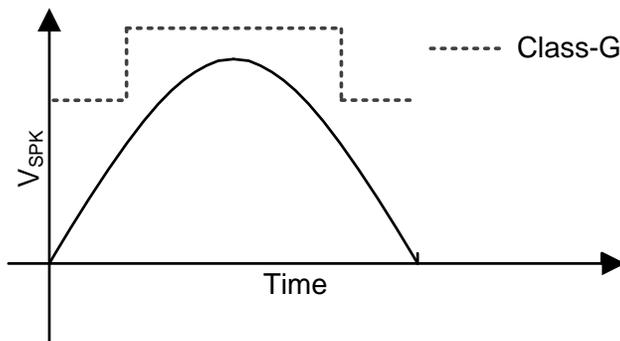
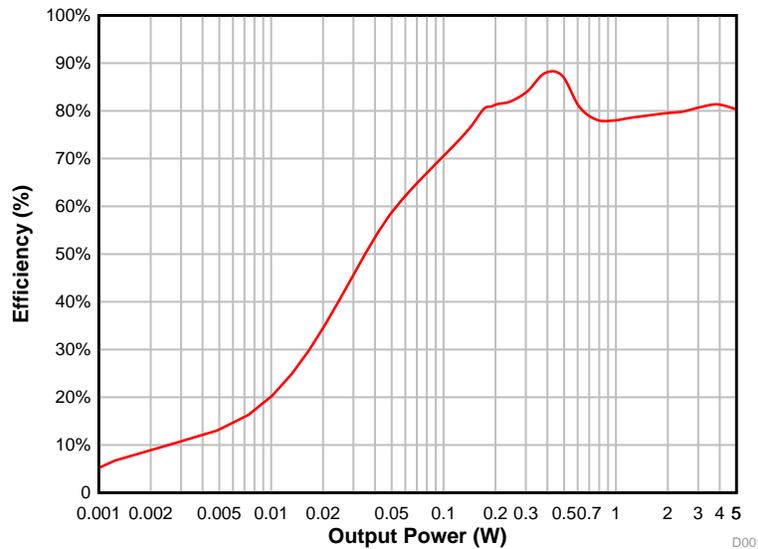


Figure 4. Class-G Profile

In this way, we maintain the higher efficiency when operating at low output power typical to the nominal supply voltage, but also extend the maximum output power the amplifier can deliver to the speaker. In figure 4, see the output efficiency achieved by TAS2562 in this type of application. Notice here that output efficiency peaks around 0.4 - 0.5 W at a maximum of 87%.



V_{BAT} = 4.2 V, R_{load} = 8 Ohm

Figure 5. TAS2562 Class-G Efficiency, 100 Hz

1.2 Class-H Boosted Amplifier

TAS2562 is also able to operate in Class-H mode. Class-H amplifiers expand on the concept introduced with Class-G. Instead of having a single voltage, the boost level is variable. With this implementation there can be several possible supply voltages as shown in Figure 6.

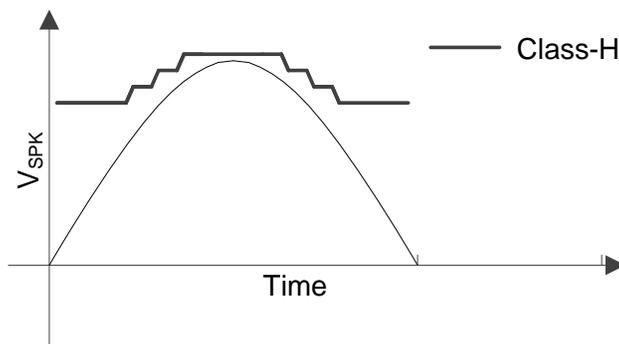
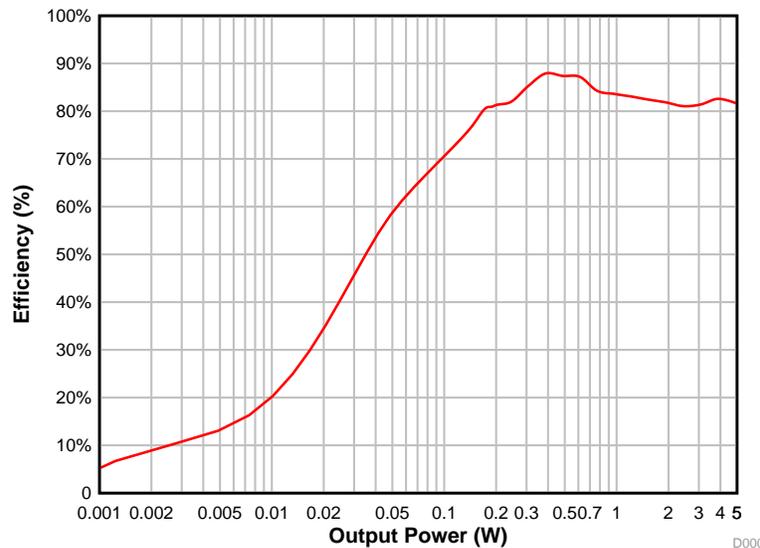


Figure 6. Class-H Profile

This enables the output to operate with just enough headroom to maintain low distortion while achieving the maximum output efficiency. As an example the output efficiency of TAS2562 operating in Class-H mode is shown below. Here we see that the amplifier has a similar profile to Class-G below 0.3 W output power. The efficiency drop-off observed in Class-G mode is not as severe in this case, and higher efficiency is maintained while the boost is active.



VBAT = 4.2 V, Rload = 8 Ohm

Figure 7. TAS2562 Class-H Efficiency, 100 Hz

The major design trade-off when selecting which mode to operate depends on the available input current. Class-H mode will require greater current drive to be available from the battery in order to achieve the fast switching necessary. Class-G mode tends to be less demanding, but will not yield the same efficiency gains as Class-H.

2 Benefits of Integrated Solution

Integrating a Class-G or Class-H boost into a Class-D audio amplifier is an excellent design choice when faced with battery voltage limitations. The solution could be pieced together with separate devices, but this would actually prove to be challenging in practice.

First, the two device approach would require greater PCB area typically is not available in handheld applications. Not only would the required components require extra PCB surface area, but there may also be placement & routing conflicts when considering the power carrying traces and resistive losses that would result in inferior efficiency.

Secondly, the synchronization of the boost may prove challenging without dedicated signal processing. Care needs to be taken to track the input signal to the amplifier to determine the proper time to enable the boost while maintaining an uninterrupted listening experience for the end user. Adequate time must be allowed for the boost to ramp and settle. This is best done with the same signal processing that is driving the Class-D amplifier.

3 Summary

Class-G and Class-H boosted amplifiers are ideal for battery operated audio devices. In the overlaid plot below, the efficiency benefits over a fixed boost system are evident. Class-G and Class-H boost modes allow the amplifier output stage to maximize overall efficiency while significantly increasing achievable output power. In addition, as an integrated solution, PCB area is kept to a minimum while delivering the best performance. In contrast, driving the output stage using a fixed boost from an external source produces the worst case efficiency.

Class-H Boost provides better efficiency than Class-G, but this mode typically requires greater maximum current delivery during the level switching events. Care should be taken when selecting the operating mode to ensure that current requirements specified in the [datasheet](#) are satisfied.

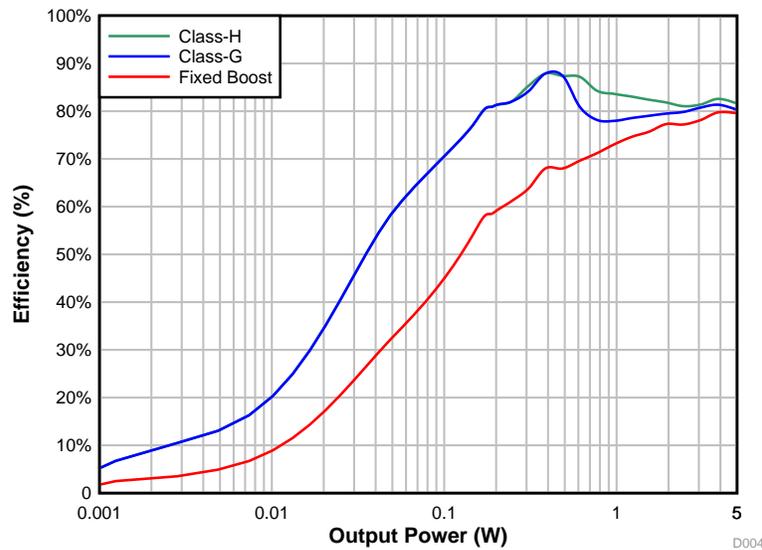


Figure 8. TAS2562 Efficiency, 100 Hz

As an additional reference, the power consumption recordings shown below were taken while playing a typical audio track. Here we can observe the benefits of Class-H and Class-G over a system designed around a fixed boost. Notice in the data captures that the estimated battery life for a 1000 mAh battery changes from 10.16 hours while in fixed boost mode, to 11.2 hours in Class-G mode, and 11.74 hours in Class-H mode. Class-H mode offers approximately 95 minute (15.5%) increase in expected battery life over the fixed boost settings.

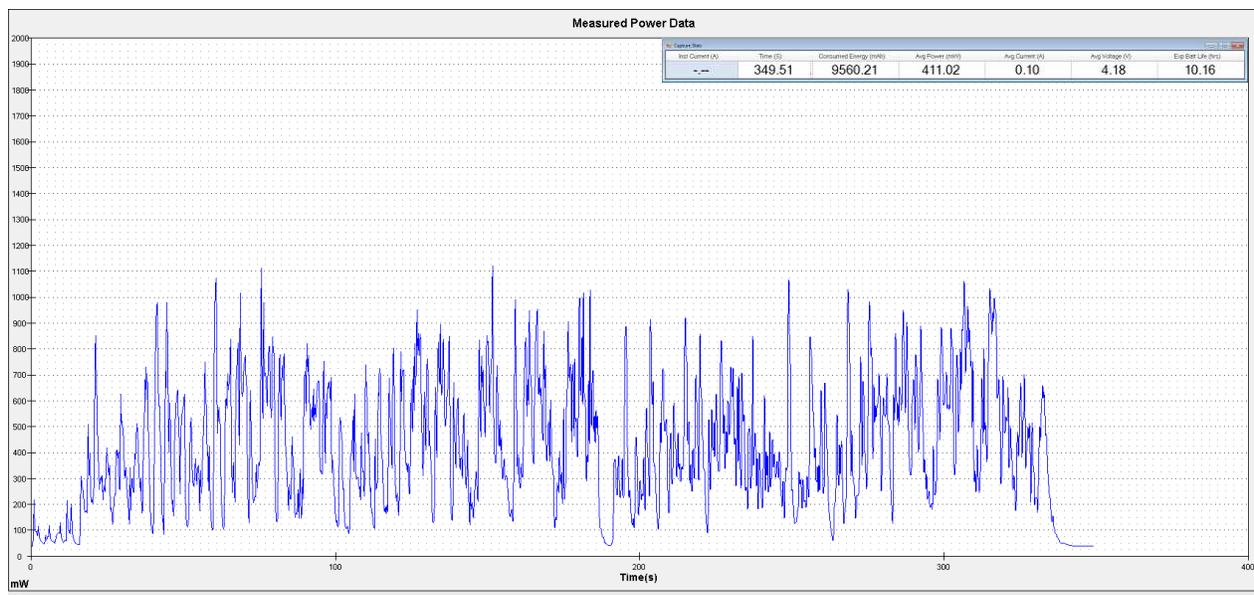


Figure 9. TAS2562 Fixed Boost Mode Power Recording

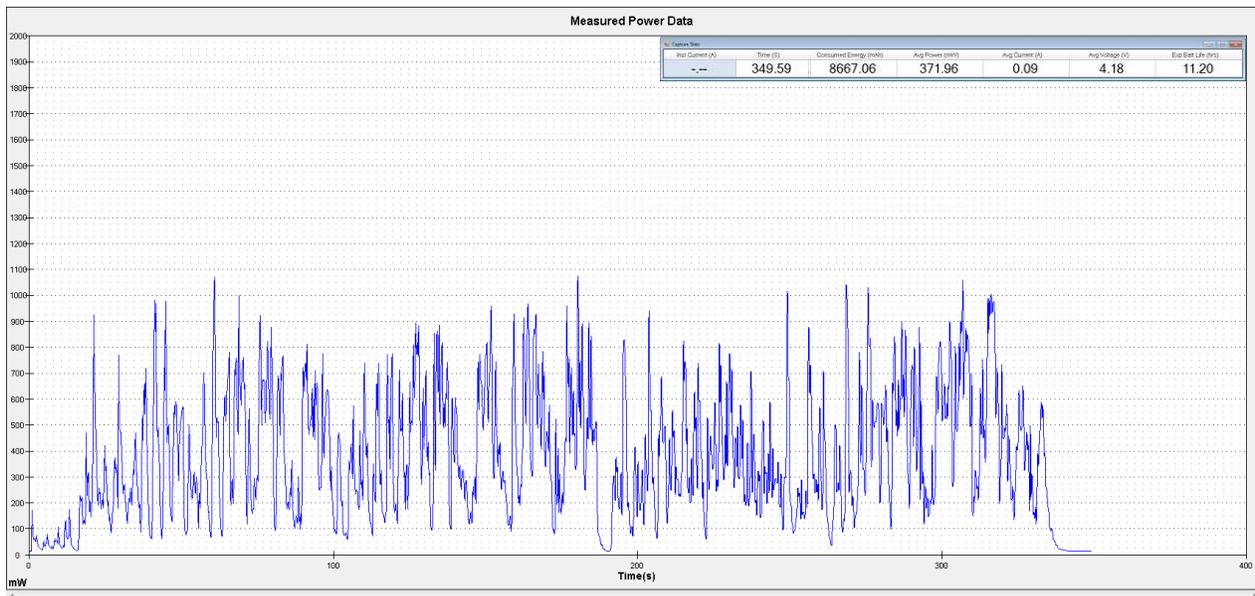


Figure 10. TAS2562 Class-G Mode Power Recording

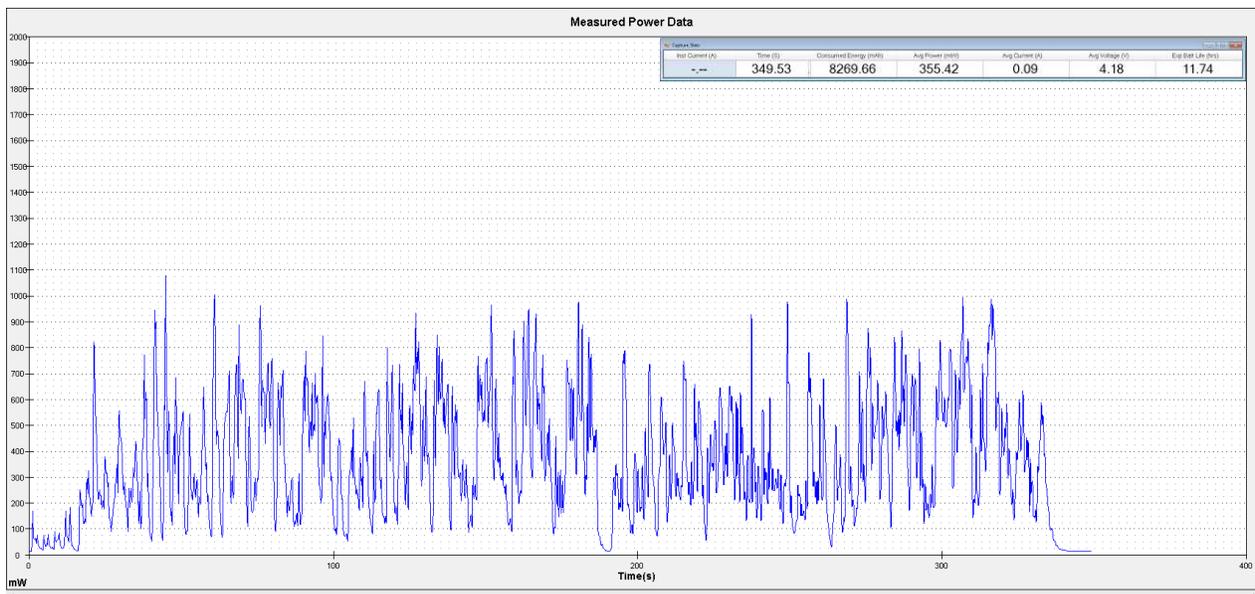


Figure 11. TAS2562 Class-H Mode Power Recording

The data for all plots in this document were taken under the following conditions:

V_{BAT} = 4.2 V, V_{DD} = 1.8 V, R_{load} = 8 Ohm + 30 uH, F_{SYNC} = 48 kHz, BCLK = 3.072 MHz

For more information, please see Texas Instruments' selection of [Boosted Class-D amplifiers](#).

4 References

- [TAS2562 Datasheet](#)

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