International
IOR Rectifier

APPLICATION NOTE

Application Note AN-1164

IR Class D Audio IC,
Operation with Single Output Power Supply

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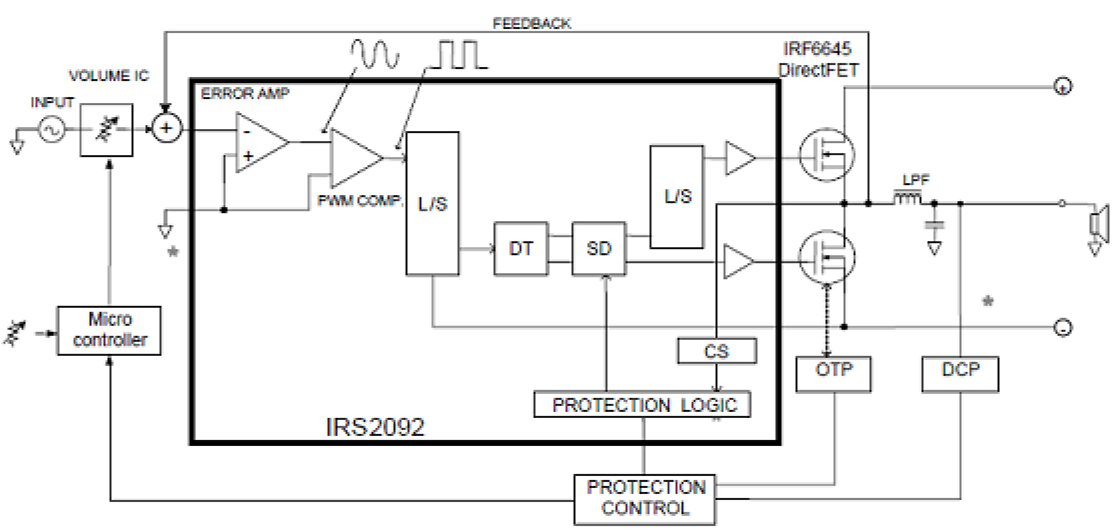
Introduction

The latest IR Class D Audio IC's feature a front end PWM generation and/or a logic protection block that is constructed on a floating well referenced to the load/speaker ground (from here on referred to as load ground). Additionally these IC's feature an internal level shifter, which level shifts these functional blocks to the negative power supply rail. However, there are designs in which there is no negative rail but only a positive one. This paper addresses a few measures required to insure proper operation of IR Class D Audio IC's with a single positive output power supply. These measures include symmetry of the positive rail voltage and its return path potential with respect to the load ground and the virtual translation of the input signal ground to the load ground using a front end differential amplifier.

1. IR Class D Audio HVIC Overview:

The IR Class D Audio IC's are built using a rugged and high voltage silicon platform. The various high voltage IC options in single and multichannel configurations offer key features such as a high speed power MOSFET drivers with internal selectable dead-time and protection functions specifically designed for Class D Audio application. These functions include bi-directional over current and under voltage lockout protections. A simplified diagram highlighting the above features is shown in Figure 1. In this diagram the single channel HVIC, IRS2092(S) is shown in a self oscillating half bridge topology.



Half Bridge Class D Audio Amplifier, IRS2092(S)
Figure 1

2. Single Rail Supply, Considerations

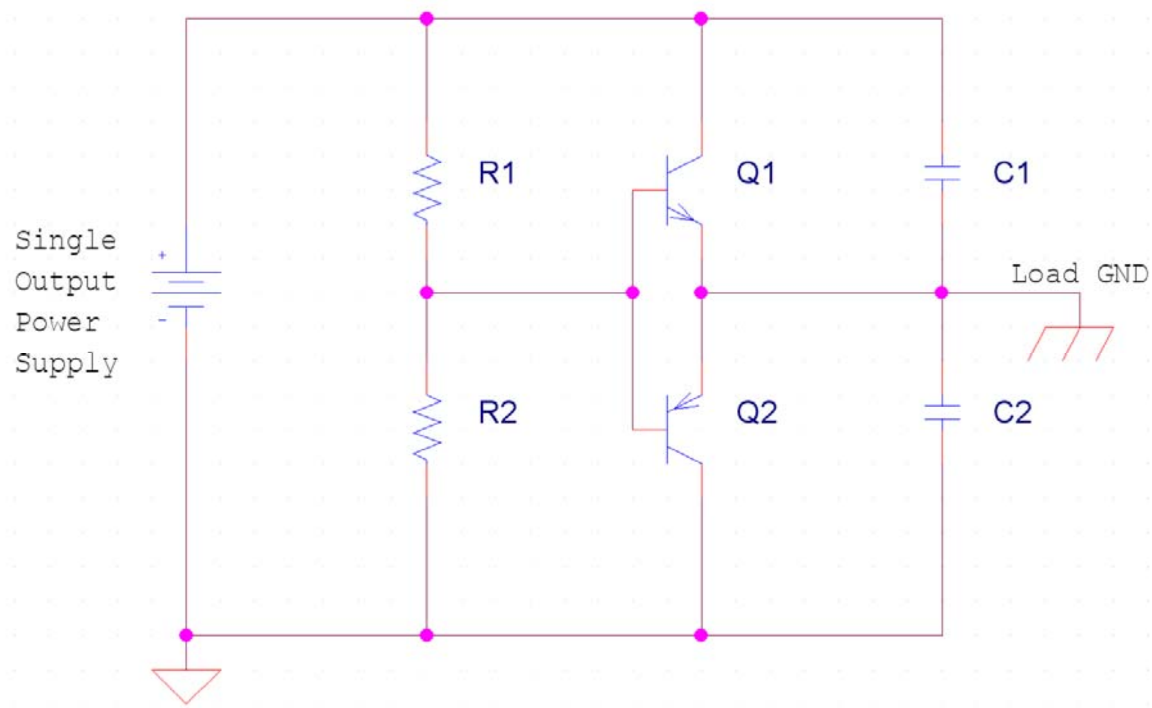
As shown in the Figure 1, typically the half bridge Class D stage is supplied with a – and a + rail with respect to the load ground, however when the design is limited to a single + rail due to power supply design constraints a couple of measures are to be considered for proper operation.

The first consideration is with regard to the symmetry of the voltage difference from the positive rail to the load ground vs. from the return path potential to the load ground. Please note, the schematic shown in Figure 2 may be helpful in following this discussion. Given this configuration the load ground maybe viewed as a virtual ground point, with voltage potential ideally at midpoint between the positive rail and its return path. The amplifier is able to modulate the load above or below this virtual ground hence generating an amplified AC output signal from the DC bus. The symmetry is critical in order to avoid distortion. Two factors affect this symmetry. One is the load ground fluctuation which may occur due to bi-directional current flow in the half bridge stage. Depending on its direction this current may charge the capacitors between the positive rail and the load ground or the capacitors between the return path and the load ground, hence disturbing the aforementioned voltage symmetry. This phenomenon is similar to bus pumping which may occur when a dual polarity output power supply is utilized, however in this case the charge pumping manifests itself as the fluctuation of the load ground with respect to the + rail and its return path. And similar to bus pumping the effect of ground fluctuation will be pronounced under low frequency input signal, higher load currents, and smaller bus capacitors. Another factor affecting this symmetry maybe the current drawn from the load ground potential by the regulator supplying the Vcc pin of the Class D Audio IC. This however may not be an issue if the Vcc is generated in a different manner, e.g. from a dedicated isolated power supply, or from a bus voltage directly.

The second consideration is with regard to the input signal reference. The input logic block of the IR Class D Audio IC's is reference to the load ground, because the control loop must see its reference in the output. However it is quite likely that the input signal to the amplifier maybe referenced to the return path or ground of the single output power supply. Therefore, it is essential that the input signal to the IR Class D driver IC is referenced to the load ground as it is fed into the amplifier. The following two sections are proposals on how to mitigate the above issues.

3. Symmetry With Respect To Load Ground

To resolve the power supply rail symmetry with respect the load ground addition of an active bleeder is recommended. While alternate solutions may exist, the tested circuit of Figure 2 may be considered as one possible solution.



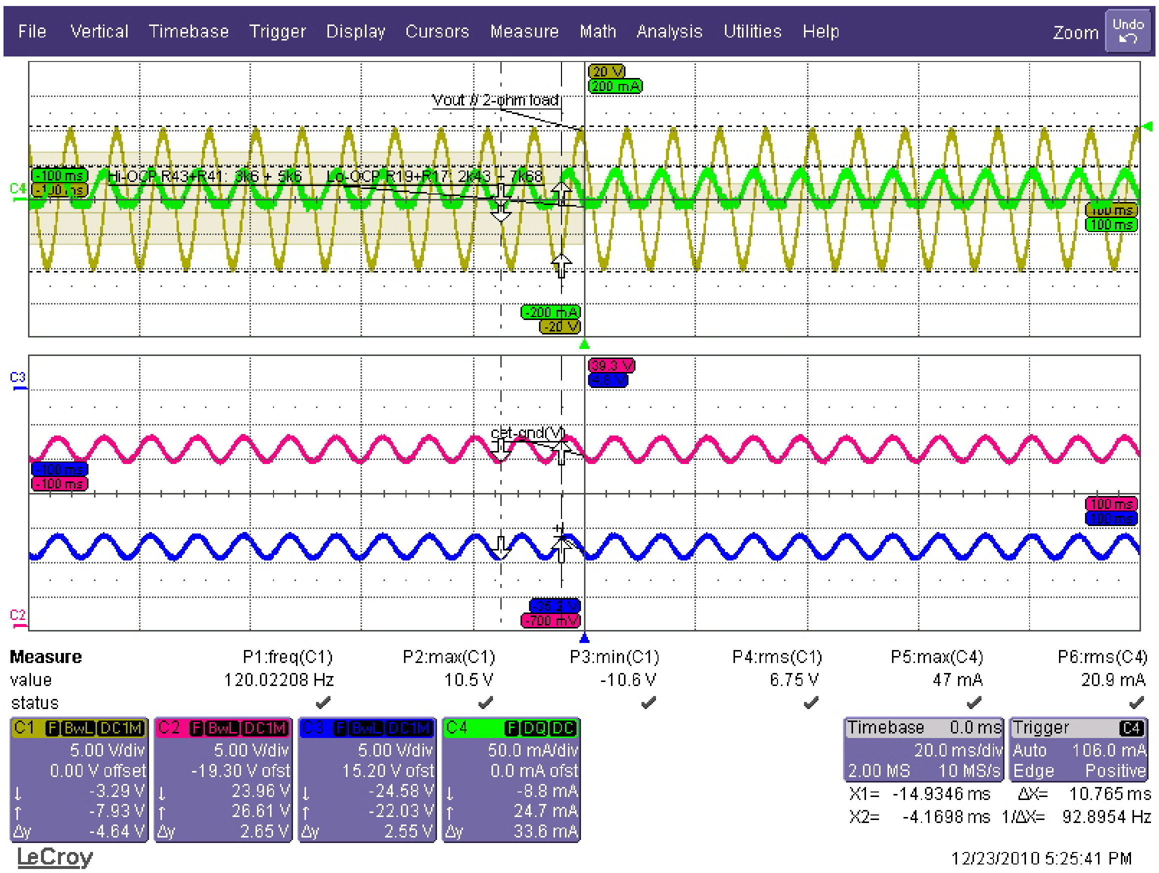
Active Bleeder
Figure 2

When load ground potential is at midpoint between the positive rail and it's return path Q1 and Q2 are to remain off, however, when the load ground fluctuates away from the + rail then Q1 will turn on and when it is pumped away from the power supply ground, Q2 will turn on. Note, the farther the fluctuation the higher the base current for the corresponding transistor and the harder it will turn on. During on state the transistor will sink current from the corresponding rail capacitor therefore allowing its voltage difference from the load ground to be reduced.

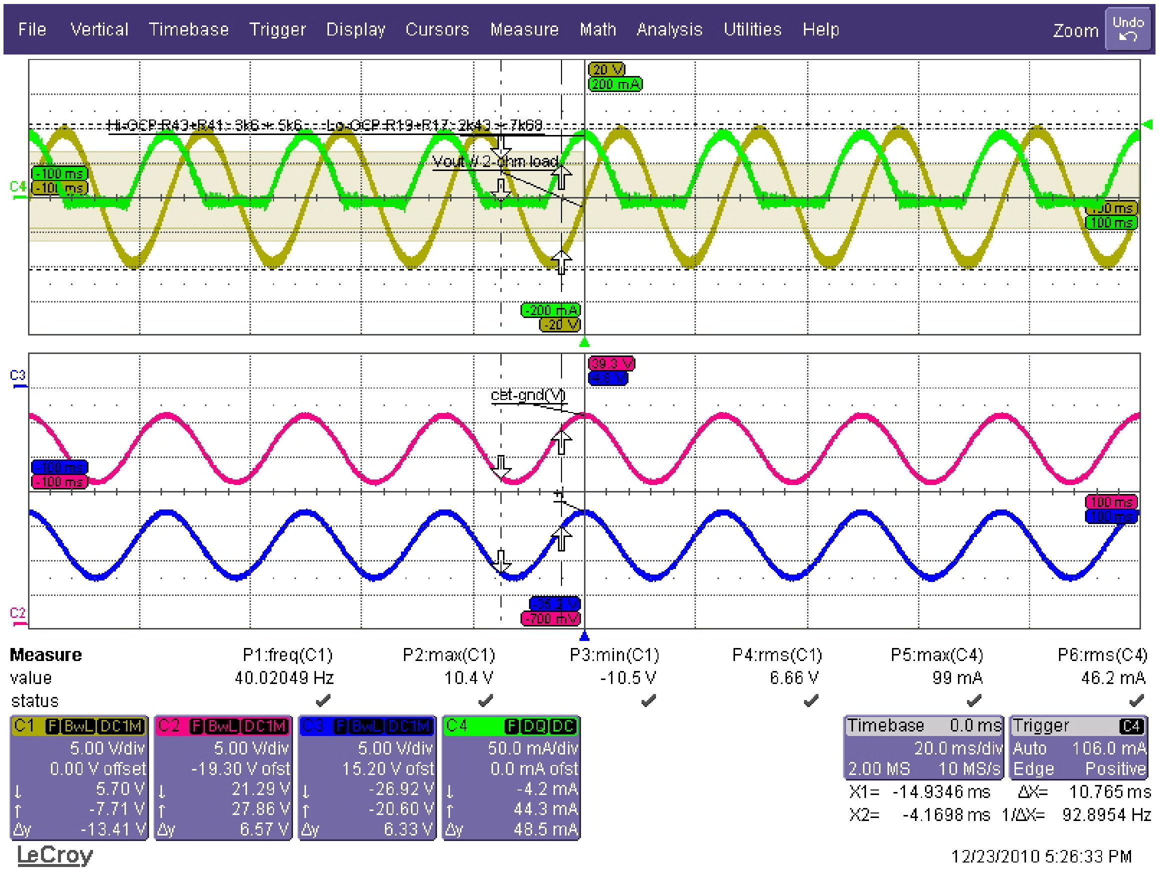
IRAUDAMP5 was modified and tested with a single +48V rail. Under no load and without the active bleeder the voltage potential from the + rail to the load ground was measured to be 38V and from the power supply return to the load ground 10V. This is because Vcc is fed from the ground. With the addition of the active bleeder the voltage potentials were corrected to 26V and 22V respectively. While the active bleeder maybe further optimized to achieve a greater degree of symmetry, a limit exists due to the drop across the BJT transistors. Moreover exact symmetry is not critical for proper operation so long

as adequate voltage headroom exists above and below the load ground for the desired load impedance and output power.

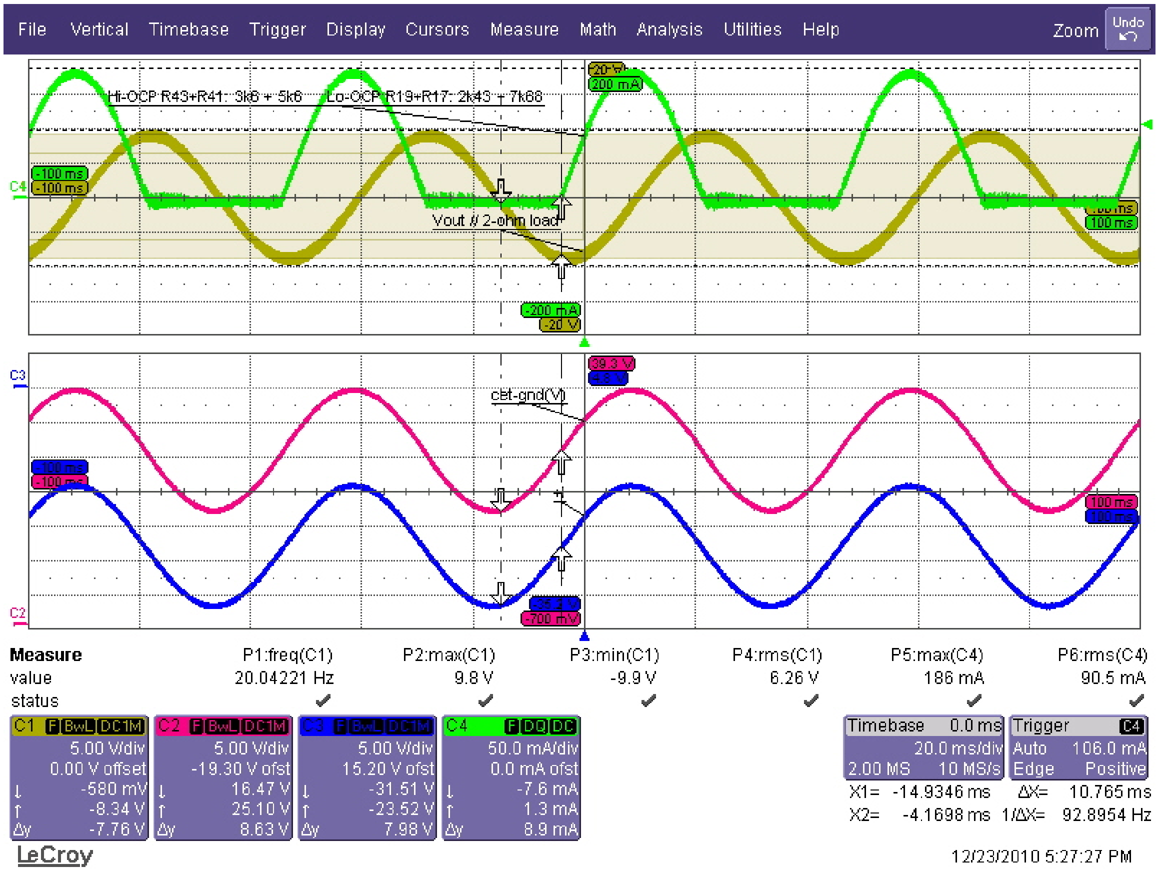
To test the dynamic performance of the active bleeder circuit, the modified IRAUDAMP5 was configured to drive a 4Ω load using low frequency input signals in the range of 20 to 120Hz. Figures 3 through 5 display the positive rail voltage and its return path voltage with respect to load ground in red and blue respectively. The output signal across the 4Ω load is shown in dark green and the current through the Q1 is shown in light green.



Dynamic Behavior of the Bleeder with 120Hz Input Signal
Figure 3



Dynamic Behavior of the Active Bleeder with a 40Hz Signal
Figure 4



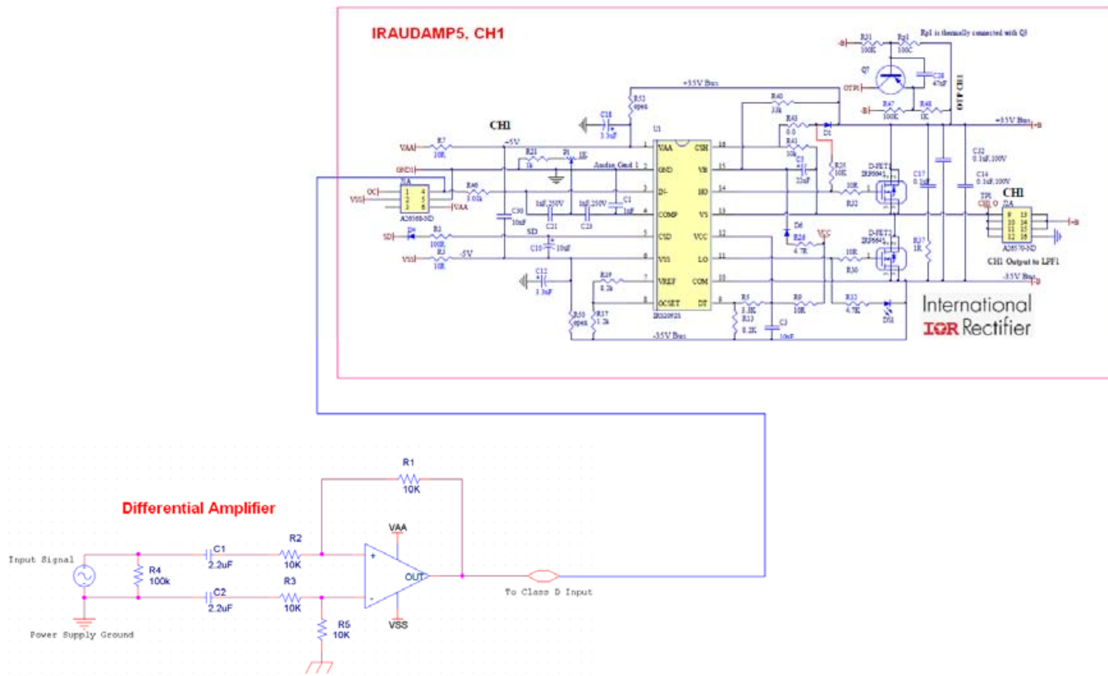
Dynamic Behavior of the Active Bleeder with a 20Hz Signal
Figure 5

As expected load ground fluctuation increases as the frequency of the input signal is reduced, hence Q1 also turns on harder in an attempt to regulate against this fluctuation. This is clear from the current through Q1, the light green waveform which is increased steadily as input signal is reduced from 120 to 20Hz.

R1 and R2 as shown in Figure 1 are high value (ohm) resistors, and since they do not carry significant current they maybe small packaged resistors, e.g. in case of through hole packages the 1/4W axial package should be more than sufficient to handle the required power dissipation. Q1 and Q2 should be rated for the full bus voltage with added margin in mind. The power dissipation in Q1 and Q2 is application related. Under normal circumstances the totem pole transistors Q1 and Q2 do not carry significant current, however, when the load ground fluctuation becomes significant as in the case of a sub woofers the amount of current increases and the transistors may dissipate significant amount of power. Obviously the worst condition is at lowest audio frequency with minimum decoupling capacitances, and highest load. As such it is critical to experimentally determine the worse case power dissipation for the active bleeder and select the transistor package size and heat sink size appropriately.

4. Input Signal’s Reference

Unless specifically accounted for, the input signal to the audio amplifier will mostly likely be reference to the power supply return. As noted previously the front end logic block of the IR Class D Audio ICs is referenced to the load or the speaker ground. To bring the two into the same reference potential the use of a differential op-amp as depicted in Figure 6 is recommended.



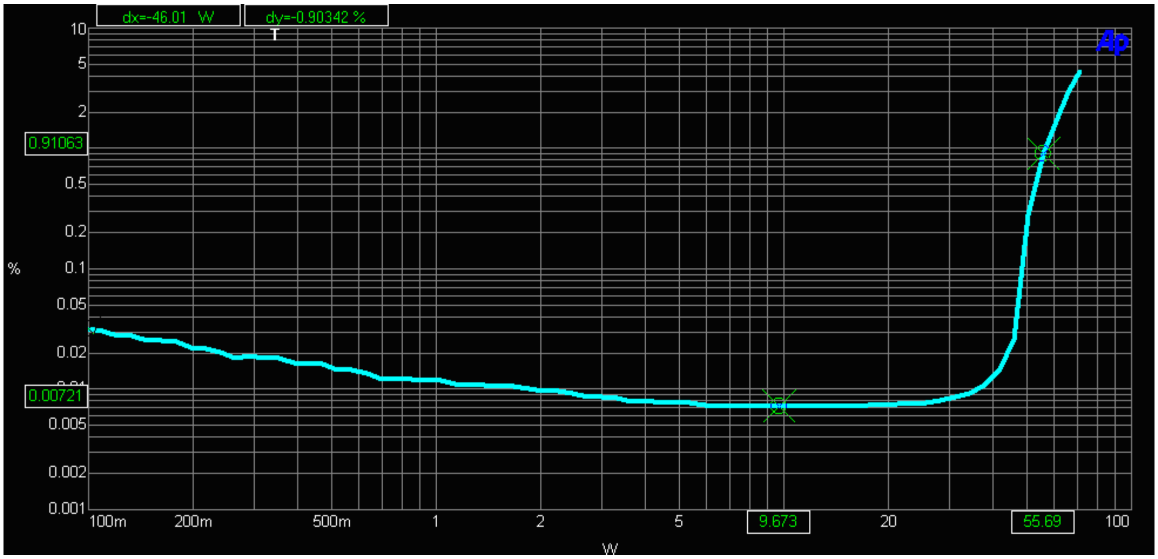
Differential Amplifier
Figure 6

Since only the difference in voltage potential between the inverting and non-inverting inputs are amplified, the resulting output will effectively be level shifted to the VAA and VSS reference point which is the desired load ground potential.

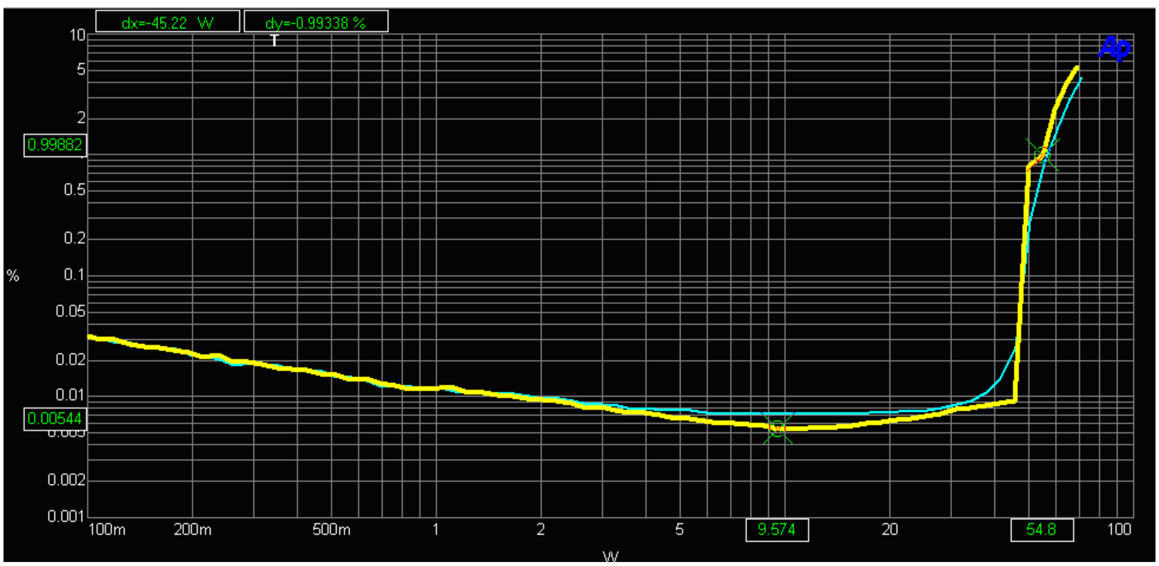
Note, while the common mode rejection ratio (CMRR) of the op-amp is critical, minimizing the mismatch between the values of resistors used to configure the op-amp in the differential mode is equally important. As such for best result it is recommended to use high precision resistors such as the ones with 1% tolerance.

5. Single Rail Operation, Performance Measurements

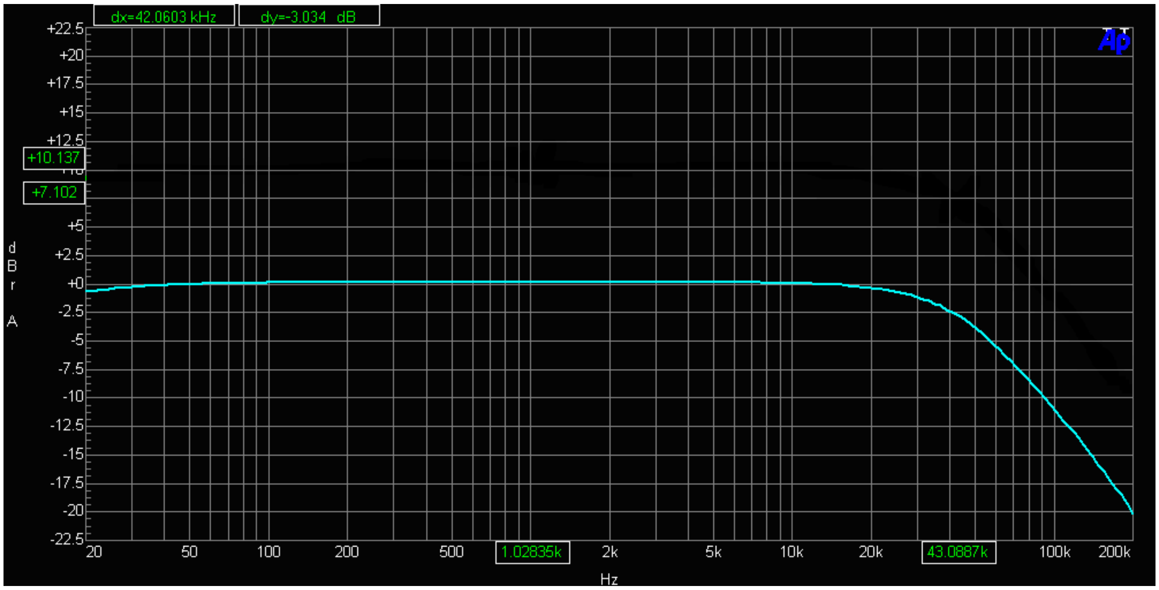
The reference design board IRAUDAMP5 was modified according to the above guidelines for 50W output power delivered into 4 ohm load, and the following performance measurements were captured using an AP equipment to verify proper operation.



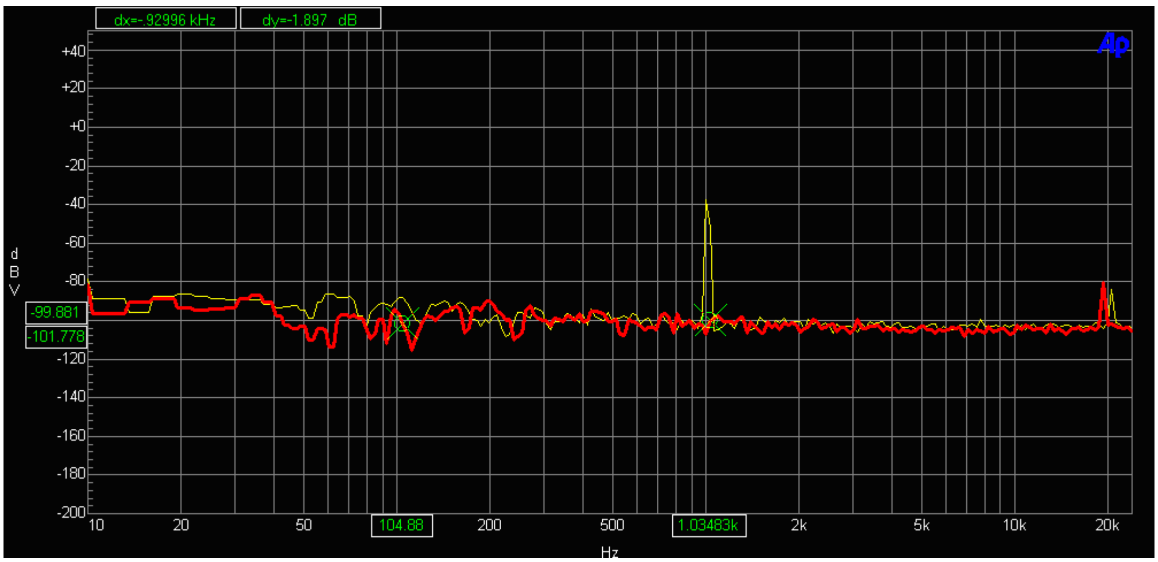
THD+N vs. Pout, 1KHz input signal
Figure 7



THD +N vs. Pout, 1KHz Input Signal (Cyan)
100Hz Input Signal (Yellow)
Figure 8



Frequency Response, Vo=2Vrms
Figure 9



Residual noise vs. Frequency (Red),
Frequency Spectrum with 10mV output (Yellow)
Figure 10

Conclusion

While originally designed to work with dual polarity supply rails, IR Class D Audio HVIC family can operate with equal performance when supplied from a single output power source. This paper addresses the two main considerations required for proper operation with single output power supply, i.e. the load ground fluctuation and the level shifting of the input signal's reference to the load ground. The proposed solutions, the active bleeder and the front end differential amplifier were tested using the reference design board, IRAUDAMP5. The resulting performance analyses measurements indicated proper operation of the IRAUDAMP5 as supplied by a single output power supply.