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Audio Amplifiers for Portable Speaker Systems

Introduction

The chronic issue with portable speaker systems is the battery life being too short. Efficient amplifiers, battery voltages and chemistry, and speaker cabinet design play a part in determining the total power required to produce a certain sound pressure level (SPL) at a certain distance and angle form the system. This paper reviews current amplifier topologies such as classes A, B, AB, D, and G as well as current all-in-one integrated circuits on the market implementing these topologies.

Amplifier Classes

Class A

Class A amplifiers are known for their very linear power delivery at the cost of power efficiency. This leads to very good sound quality, but it is not optimal to be used in portable applications due to efficiency being typically below 50% at best [1]. This topology has also the least parts count than all the others due to it only needing a single transistor with three or four resistors to bias it.

Class B

The TDA2005R from ST Microelectronics is an example of this type of amplifier and is advertised as having 10% Total Harmonic Distortion (THD) at 20 W at a load of 4 Ohms [2]. This type of amplifier uses an additional transistor to provide a second means for current to flow through to the output with one providing current from a positive voltage supply and the other transistor from the negative voltage supply. This improves the efficiency compared to class A, but also creates the problem of properly compensating for the turn-on voltages (Vbe) of the transistors [3].

Class AB

The problem of class B is that the transistors might turn on at the same time causing a potential short between the two power supplies. This is mitigated by biasing the inputs of the transistors such that they won’t be “on” at the same time. This requires complex circuitry that includes many more components compared to class A while being much more efficient [4]. An example of this type of amplifier is the Texas Instruments LM3886 chip which has been around since 1999 and is very popular in the do-it-yourself community for home audio. This chip is also the flagship class AB amplifier one will see in many amplifiers due to its high power output and low external components. This amplifier has a much lower THD at around 0.04% as compared to the previously mentioned class B chip [5].

Class D

All three of these amplifiers so far have bad heat dissipation issues for high-power applications leading to the need for large heat sinks, but a newer topology, class D, increased efficiency up to near 90+% in cases when enough load is put on the amplifier [6], [7]. Efforts are still being made to optimize this topology like Iversen [7] and their research into battery powered class D amplifier load voltage and impedance matching. In their study, they had a THD of 0.005%, but this was also a much lower power amplifier than the previous two amplifiers mentioned earlier. A better comparison would be the TPA3118D2-Q1 from Texas Instruments which has a THD of 0.1% at 25 W and Vcc of 21 V [8]. This THD is worse than the class AB amplifier by a large margin, but it is much more efficient at 90% as output power goes above 30 W.

Class D amplifiers compare the analog input signal with a square wave (sometimes ramp) and then drive an H-bridge MOSFET array with the resulting signal creating a very large output signal with significant distortion. This distortion is usually at a frequency well above human hearing and is easily filtered out, but this switching loss and subsequent filtering still requires energy that, at low output power, becomes significant enough to decrease the output power efficiency by 50% to 60%. A method of mitigating these losses in lower power conditions (when the volume is turned down) has been developed, but this technology hasn't been implemented in commercial products yet [9].

Class G

In order to solve the relatively low efficiency of class AB amplifiers (as compared to class D), class G was developed. This newer topology uses multiple voltage supplies that the amplifier will choose from according to the load impedance and input voltage in order to decrease the peak voltage when it can. Other than the voltage supply switching, class AB and G are very similar. For class G, there is a positive and negative high voltage and a positive and negative low voltage supply that the controller chooses from while class AB only has the high voltage supplies. The low voltage one is chosen when the impedance is low and/or the demanded volume of the signal is lower, so the output transistors will not experience as high of an output peak voltage and dissipate the power necessary to decrease the output voltage [10]. These amplifiers are typically used for headphones or miscellaneous other things such as PLC outputs, but aren't seen in loudspeaker amplifiers as often especially when compared to class D ones.

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[7] N. Iversen, H. Schneider, A. Knott, and M. Anderson, "Efficiency investigation of switch-mode power audio amplifiers driving low impedance transducers," In Proc. Audio Engineering Society 139th Convention, 2015, pp. 1-8.

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[9] M. Hoyerby, J. Jakobsen, J. Midtgaard, and T. Hansen, "A 2 x 70 W monolithic five-level class-D audio power amplifier in 180 nm BCD," *IEEE Journal of Solid-State Circuits,* vol. 51, no. 12 Dec.. pp. 2819-2829, 2016.

[10] S. Wen, C. Chen, C. Hsiao, "Load-adaptive class-G amplifier for low-power audio applications," U. S. Patent 2019,019,9300, 17 Jun., 2019.