DESIGN OF CLASS-D AUDIO POWER AMPLIFIERS IN SOI TECHNOLOGY

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Abstract

The design of integrated class-D audio power amplifiers is discussed. The amplifiers are realized in an SOI based BCD-technology that is inherently free from latch-up. The core of a class-D amplifier is the switching output stage. Accurate control of the switch timing is essential for good audio performance. In order to achieve this, detailed knowledge of the transient dynamics is necessary. Robustness is the crucial thread throughout the design. Robustness is complicated by high voltages and the switching of large currents in the output stage. Further the output stage needs to be robust against all sorts of fault conditions such as short circuits and electro-static discharge.

1. Introduction

The operating principles of class-D amplifiers have been known for a long time, but only recently semiconductor manufacturers are able to produce reliable integrated class-D amplifiers of sufficient quality [1]. The audio performance of modern class-D amplifiers equals or even exceeds that of conventional class-AB amplifiers. The distinguishing feature of class-D amplifiers is the high efficiency which allows for smaller heatsinks or higher output power before running into thermal limitations. This is especially advantageous in multi-channel systems such as DVD receivers. The main drawback of class-D amplifiers is that the switching at the output is a source of electro-magnetic interference (EMI). A careful optimization of the application is crucial. Also, class-D amplifiers require an external lowpass filter that contains at least one inductor which adds to the cost.

2. Operating Principle

The core of a class-D amplifier is the switching output stage. A block diagram is shown in figure 1. The switching output stage consists of two large switches $S_H$ and $S_L$ and a switch control block. The function of the output stage is a...
simple one: switching the output node $V_{\text{out}}$ up and down between the supply rails $V_{\text{SSP}}$ and $V_{\text{DPP}}$. This results in a square wave signal with a frequency that generally lies between 200kHz and 800kHz. The audio signal is embedded in the output signal using some form of pulse-width modulation (PWM). Many forms of PWM exist [2], all having their specific advantages and disadvantages. However, a discussion on PWM is beyond the scope of this paper.

![Figure 1. Class-D output stage](image)

Ultimately both the audio performance and EMI are largely determined by the switching output stage. Accurate control of the switch timing is essential to reproduce the PWM signal with sufficient fidelity. Usually, the switch control includes a break-before-make arrangement that prevents the power switches $S_{L,H}$ from conducting simultaneously. This results in a period of time where control of the output voltage is lost which is appropriately called the *dead time*. During the dead time the output current $I_{\text{out}}$ flows through one of the fly-back diodes $D_{L,H}$. Dead time is one of the dominant sources of distortion in class-D amplifiers [3].

### 3. SOI Technology

Design starts with the selection of an appropriate technology. For class-D audio amplifiers a BCD (Bipolar, CMOS, DMOS) processes is an almost inevitable choice. The bipolar transistors are indispensable for analog circuits where noise and offset are important. The CMOS allows for integration of modest size logic circuits for interfacing and control functions. Finally, DMOS transistors are almost perfect power switches featuring high breakdown voltage and low on-resistance plus the ability to conduct current in both directions.

A process that is particularly suitable for switching applications is A-BCD [4] which is an SOI based BCD technology. The dielectric isolation between the