Abstract: This application note describes a new generation of digital-input Class D audio amplifiers that achieve high PSRR performance, comparable to traditional analog Class D amplifiers. More importantly, these digital-input Class D amplifiers provide additional benefits of reduced power, complexity, noise, and system cost.

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Introduction

Electronics vendors commonly use high-efficiency, filterless, analog-input Class D amplifiers to manage the power requirements of portable audio speakers found in cell phones, tablet computers, and personal navigation devices. These Class D amplifiers allow direct connection to a battery, which minimizes losses and reduces component count. The amplifiers also achieve > 70dB PSRR performance, which is important to avoid audible buzzing with 217Hz demodulated GSM signals.

Analog-input Class D amplifiers normally require a digital-to-analog converter (DAC) and line driver amp on the application processor (Figure 1). Unfortunately, this adds die cost, power, and noise to the speaker output. These Class D amplifiers also require careful board design to avoid degradation because of signals coupling onto the analog board routes.

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Figure 1. Conventional system with analog-input Class D speaker amps. The DAC and line driver amp on the application processor add die cost, power, and noise to the speaker output.
Digital-input Class D audio amplifiers are immune to most board design issues. Single-channel Class D amplifiers can be placed at remote locations on a board to minimize the routing of the high-current battery and speaker load connections. These amplifiers do not need the DAC and line driver amp of analog-input Class D designs. Thus, space and system costs drop and designs are simpler.

**Simplified System Design**

The most common type of digital-input for an amplifier is pulse-density modulation (PDM) which requires only two wires: PDM_CLK and PDM_DATA. Single-bit PDM data is created with an oversampled delta-sigma modulator on the application processor (Figure 2).

![Figure 2. System with a PDM-input Class D speaker amp requires only two wires and uses oversampled delta-sigma modulator on the application processor to create single-bit data.](image)

A few amplifiers will accept pulse-code modulated (PCM) or I²S data, which requires three wires: BCLK, LRCLK, and DIN. The PCM data format does not require a modulator or upsampling of the data on the application processor (Figure 3). Some older implementations of PCM-input amplifiers also require a clean master clock (MCLK) to derive a jitter-free sampling clock. Newer PCM input amplifiers like the MAX98355 no longer require the MCLK input so pin count, power consumption, and board complexity are all reduced.

![Figure 3. A system with a PCM-input Class D speaker amp uses three wires but does not require a modulator or upsampling of the data on the application processor.](image)

Older digital-input amplifiers offer adjustable sample rate and/or bit depth that, in some cases, require complex programming of
the amplifier. Newer generations of digital-input amplifiers like the MAX98355/MAX98356 automatically detect a wide range of sample rates and bit depths to self-configure without any programming.

In a multichannel implementation the digital-input Class D audio amplifier reduces the number of external capacitors and routed lines on the board. Only PDM_CLK and PDM_DATA lines are needed for PDM inputs to provide stereo data to two Class D amplifiers. The BCLK, LRCLK, and DIN lines are needed for PCM inputs to provide stereo data. As a comparison, a stereo analog-input Class D amplifier will normally require two differential input signals (four wires) to be routed with AC-coupling capacitors. (See Figures 1, 2, and 3.)

Most digital-input amplifiers require both a low digital-supply voltage (1.8V) and a high speaker-supply voltage (2.5V to 5.5V). Now board design and component count can be simplified by using a single-supply Class D amplifier like the MAX98355/MAX98356.

Jitter Tolerance and Clock Generation

Digital-input Class D audio amplifiers do, admittedly, present a new challenge for clock jitter. For good audio quality, most digital-input amplifiers require fairly low levels of jitter on BCLK or PDM_CLK. The jitter tolerance is often not quoted in the data sheet; when jitter tolerance is quoted, the typical specification is ~200ps of RMS jitter. High levels of clock jitter will typically degrade either the amplifier's dynamic range or the full-scale THD+N performance.

In many systems the reference oscillator for the application processor is not a convenient multiple of the PDM_CLK or BCLK, so providing a low-jitter clock for the amplifier is not easy. For example, 13MHz is a common crystal frequency used for GSM phones and 27MHz is commonly used in video solutions. Neither of these reference frequencies is a convenient multiple of the 44.1ksps or 48ksps audio sample rates. These systems will, therefore, often implement a complicated fractional-N PLL to create the clock for the audio. In some cases, the solution will require a separate audio reference oscillator which increases complexity and bill of materials (BOM).

An alternative, and preferable, solution is a digital-input amplifier that can tolerate very high clock jitter without degrading the audio performance. Such an amplifier will reduce system complexity. In the simplest case, a cycle-skipping clock can be used to generate the PDM_CLK or BCLK, but this generates extraordinarily high jitter. If a 13MHz reference clock is cycle skipped to create a 6.144MHz PDM_CLK (48ksps x 128OSR), then the peak jitter will be 38.4ns and the RMS jitter will be 22.2ns (Figure 4). This represents two orders of magnitude higher jitter than most DACs can tolerate. The MAX98355 PCM and MAX98356 PDM Class D audio amps, however, still produce near 100dB dynamic range performance with this amount of clock jitter. A cycle-skipped clock can be created with a very small number of digital gates on the application processor. They do not need the oscillator or a loop filter that would otherwise be required in a PLL solution. See Figure 5.

![Figure 4. A 12.288MHz MCLK from a cycle-skipped 25MHz clock.](image-url)
Jitter Tolerance Test Results

Test results show that the MAX98355's dynamic range does not degrade with the cycle-skipped jittered clock. The MAX98355 outperforms the "120dB DAC" by more than 20dB with the jittered clock. Further details on jitter tolerance in delta-sigma DACs can be found in application note 5477, "Analyzing Audio DAC Jitter Sensitivity."
Conclusions

Digital-input filterless Class D audio amplifiers like the MAX98355/MAX98356 allow simple board-level implementation, a low BOM, high efficiency, low EMI, and high output power. These amplifiers are available in a 1.345mm x 1.435mm, 9-pin WLP package and produce as much as 3.2W of output power.

Related Parts

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<tr>
<th>Part</th>
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<tbody>
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<td>MAX98355A</td>
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<td>MAX98355B</td>
<td>PCM Input Class D Audio Power Amplifiers</td>
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<tr>
<td>MAX98356</td>
<td>PDM Input Class D Audio Power Amplifier</td>
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