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APPLICATION NOTE 3924

Thermal Considerations for a UCSP Package

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Abstract: The amount of power that an audio amplifier will dissipate is primarily limited by its package and external heat sink (whether a copper plane on the PCB or a metal heat sink). While more efficient amplifiers like Class D do not dissipate as much as conventional Class AB amplifiers, all amplifiers dissipate some power as heat. This application note discusses the power-dissipation capabilities of the UCSP™ package, and how that package can limit dissipated output power compared to other package options.

The UCSP Package

The UCSP is a packaging technology that eliminates the traditional plastic package used to encapsulate integrated circuits (ICs). Soldering the silicon directly to a PCB saves board space, but at the sacrifice of some of the advantages of a traditional package, especially heat dissipation.

Most packages used for audio amplifiers have some type of exposed pad that allows the substrate of the IC to be connected directly to either a heat sink or the PCB's ground plane. This design provides a low-thermal impedance path for the heat transferred from the IC to its surroundings, and thus keeps the device from overheating.

With a UCSP package, however, the IC is directly soldered to the PCB using bumps on the bottom surface of the device. While there are direct paths from the substrate to the PCB through the ground bumps and these bumps have a low thermal impedance, their area is much less than a typical exposed pad. Consequently, thermal dissipation is reduced. Nonground bumps also help dissipate heat, but at a reduced capacity compared to ground bumps. Top-side thermal dissipation through a heat sink is impractical due to the space constants of most systems using UCSP devices. The UCSP package is, moreover, not as mechanically robust as other packages typically used with heatsinks. A UCSP can actually become damaged while in contact with the heat sink. The thermal capabilities of a UCSP device are therefore determined by combining the heat dissipated by the grounded bumps with the rest of the bumps on the device.

Power Dissipation

Audio amplifiers are generally offered in multiple packages and characterized using the package option with the most power dissipation. In most cases these packages prevent the power dissipated by the package itself from limiting the possible output power.

Most ICs list the continuous power dissipation that is possible with each package option in the Absolute Maximum Ratings section of the data sheet, as shown in **Figure 1**. Packages with an exposed pad (TDFN in this case) generally dissipate the most power. Note that the UCSP dissipates significantly less power than the exposed package device.

Continuous Power Dissipation (T_A = +70°C)
9-Bump UCSP (derate 5.2mW/C above +70°C)...............412mW
10-Bump TDFN (derate 24.4mW/C above +70°C).........1951mW
10-Bump µMAX (derate 10.3mW/C above +70°C)..........825mW

Figure 1. Typical Absolute Maximum Ratings for continuous power dissipation in an audio amplifier.

Calculating Output Power Limits

When considering a package without an exposed pad, one must recognize the possibility of reduced output power caused by the package's reduced power dissipation. Alternatively, a higher load impedance can be used to maximize the efficiency and, thus, minimize the dissipation.

Class AB Amplifiers

Calculating the achievable output power depends on the type of amplifier used. Manufacturers of Class AB amplifiers typically provide a plot of power dissipation vs. output power similar to **Figure 2**. Depending on the amplifier, multiple graphs may be provided for different supply voltages and load impedances.

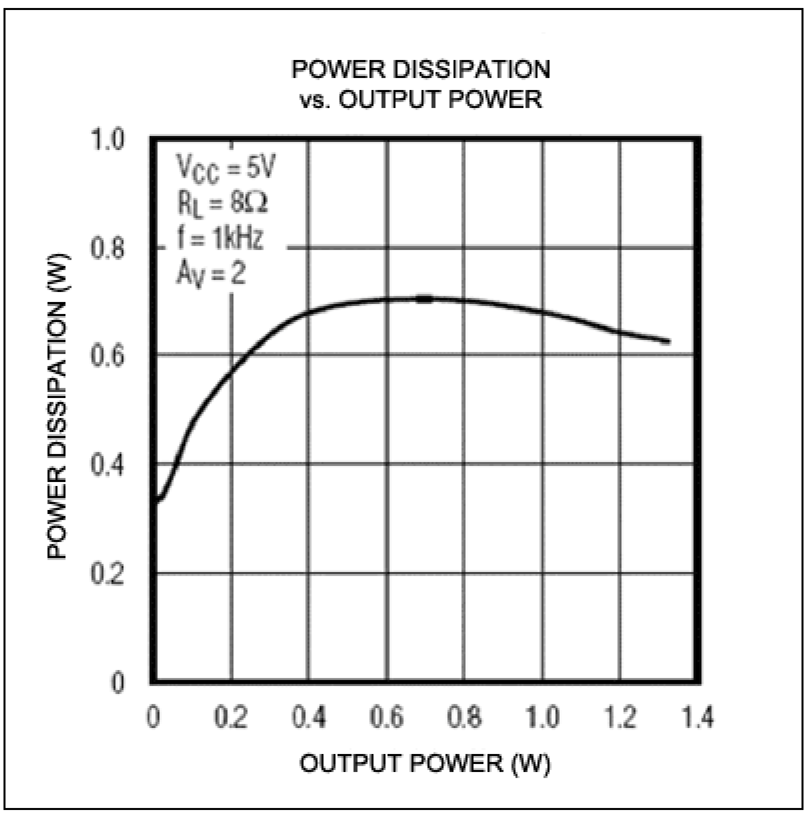

Figure 2. Power Dissipation vs. Output Power for a Class AB amplifier.

Compare the continuous power dissipation data from the Absolute Maximum Ratings (Figure 1) with the Power Dissipation vs. Output Power (Figure 2) to determine the output power possible in a given package. In this case the TDFN and µMAX® packages will not limit output power while the UCSP does. Even though this example amplifier is rated to 1.1W continuous power, only 100mW is possible in the UCSP package.

Class D Amplifiers

Class D amplifiers typically provide efficiency instead of power dissipation curves, as shown in **Figure 3**.

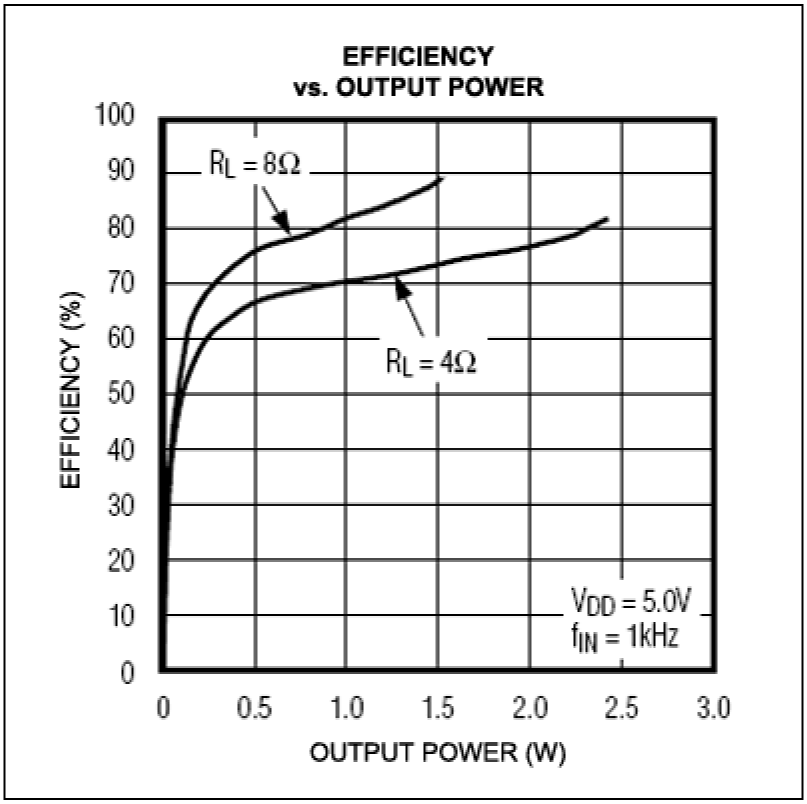

Figure 3. Efficiency vs. Output Power for a Class D amplifier.

The efficiency of Class D is much higher than for a Class AB amplifier, so the power dissipation for the same output power will be much lower. Power dissipation can be calculated using the following formula:

$$P_{Dissipation} = \frac{P_{OUT}(1-\eta)}{\eta}\text{, where } \eta = \text{efficiency} / 100$$

To achieve 1.1W of continuous output power this amplifier will dissipate 225mW. Since this power dissipation is lower than maximum output power of all the possible packages shown in Figure 1, the same output power is thus possible with each package option, including the UCSP.

Audio Source-Material Considerations

The output power of an audio amplifier is generally calculated using a 1kHz sine wave at 1% (< 6W) or 10% (> 6W) THD+N. In real-world applications the amplifier will be used to reproduce voice, music, or sound effects, all of which contain less energy than sine waves. **Table 1** shows the RMS energy level in a few common signals.

Table 1. RMS Energy in Typical Audio Source Material

Audio Source Material	Ratio of RMS Level to Peak Level (dB)
Sine Wave	-3
Rock Music	-10.8
Telephone Ringing	-12.3
Classical Music	-15.8

This data show that to achieve the same output power and, as a result, power dissipation, the output signal must have a significantly higher peak voltage for normal audio content when compared to sine waves.

Take, for example, the previously mentioned Class AB amplifier in a UCSP package. The continuous output voltage possible with sine waves is $2.5V_{P-P}$. With the rock music example in Table 1, the same package can withstand $6.2V_{P-P}$ at the output without exceeding the package's power dissipation capabilities. A sine wave with the same peak voltage would result in 600mW delivered to an 8Ω load.

Conclusion

Clearly one must consider the power dissipation of the various package options when choosing an audio amplifier. In many cases only some, not all, package choices can achieve the same continuous output power. In fact, the UCSP often sustains less continuous power than packages with an exposed pad. One can overcome this power dissipation problem not by abandoning the benefits of UCSP, but by using more efficient Class D amplifiers instead of Class AB. That design modification will allow the UCSP package to be used in many more applications.

A translated, similar version of this article appeared in the February 2007 issue of *EE Times Japan*.

Related Parts		
MAX9701	1.3W, Filterless, Stereo Class D Audio Power Amplifier	Free Samples
MAX9705	2.3W, Ultra-Low-EMI, Filterless, Class D Audio Amplifier	Free Samples
MAX9712	500mW, Low EMI, Filterless, Class D Audio Amplifier	
MAX9716	Low-Cost, Mono, 1.4W BTL Audio Power Amplifiers	Free Samples
MAX9717	Low-Cost, Mono, 1.4W BTL Audio Power Amplifiers	Free Samples
MAX9718	Low-Cost, Mono/Stereo, 1.4W Differential Audio Power Amplifiers	Free Samples
MAX9719	Low-Cost, Mono/Stereo, 1.4W Differential Audio Power Amplifiers	Free Samples

MAX9773	1.8W, Filterless, Ultra-Low EMI, Stereo Class D Audio Power Amplifier

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