

Extracting efficiency in mobiles and portable stereo audio

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Portable electronic products, such as mobile phones, are integrating more and more multimedia capabilities. This has created great interest in incorporating stereo capabilities. The mono architecture is used for voice amplification, polyphonic ringing and in some cases hands free speakerphone capabilities. While adequate, this approach does not provide a satisfactory solution for high quality music playback.

Today, portable devices such as 3G mobile phones or portable media players can easily offer an audio 3D effect through digital processing. With such equipment, stereo headset listening is also embedded, and thus right and left signals are available out of a DAC or an FM tuner, for example. While the headset power is around 10 mW into a 32 Ω load, the main loudspeakers can easily draw to 1W into an 8kΩ load. At these power levels, the design challenge is to provide high efficiency with a clean audio signal. This is compounded since the need is to provide a stereo solution instead of a mono approach.

A Class AB solution offers very low THD+N, but the efficiency is limited in the best case to approximately 70%. A simplified schematic of this solution is described in Figure 1. This is the most commonly used output stage topology in linear monolithic audio amplifiers for portable electronic equipment. Let's have a look at the roots of this topology.

Class A, Figure 2, is made up of two transistors: one is dedicated to biasing and the other is used in voltage-follower configuration. As both of them operate in their active region, the distortion level is near zero for high-fidelity

systems. The price to pay for this linearity is efficiency: the biasing structure must handle peak currents and the other draws a significant amount of current. Thus the maximum efficiency will be achieved at maximum signal levels with a poor 25%.

$$\eta_{max} = \frac{P_{OUT}}{P_{SUPPLY}} = \frac{1}{2} \cdot \left(\frac{V_{CC} \cdot I_Q}{2 \cdot V_{CC} \cdot I_Q} \right) = 25\%$$

(equation1.gif) not included in article

In Class B, Figure 3, output stage is made of a push pull configuration where two transistors are not active simultaneously. The calculation of the best case regarding efficiency brings a 78.5% value.

$$\eta_{max} = \frac{P_{OUT}}{P_{SUPPLY}} = \left(\frac{V_{CC}^2}{2RL} \right) \left(\frac{2RL}{V_{CC}^2} \right) = 78.5\%$$

(equation2.gif) not included in article

In a configuration using an NPN and PNP transistors, the output will pass through a dead zone of 2 times V_{BE} (1.4V). This will lead to an unacceptable sound quality especially when the load is a sensitive receiver, such as an earpiece.

AB is the midpoint class Class AB topology is made of a biased Class B output stage. To correct the weakness of the push pull configuration, the aim is to always ensure one transistor at least is in its linear region when we cross the dead zone. There are devices that ensure THD+N at 0.01%. Today the linear devices used in low power applications for portable electronic equipments are Class AB amplifiers, most of the time

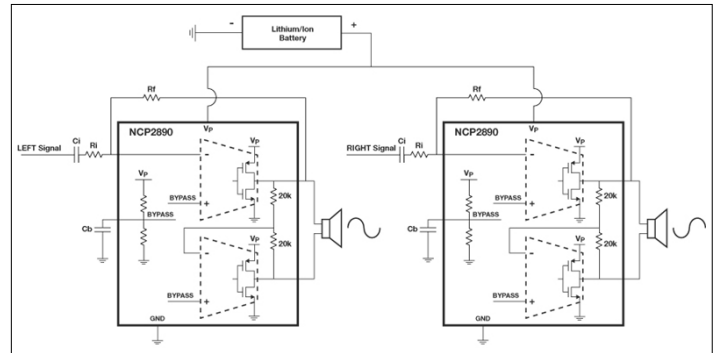


Figure 1: Stereo schematic with Class AB solution.

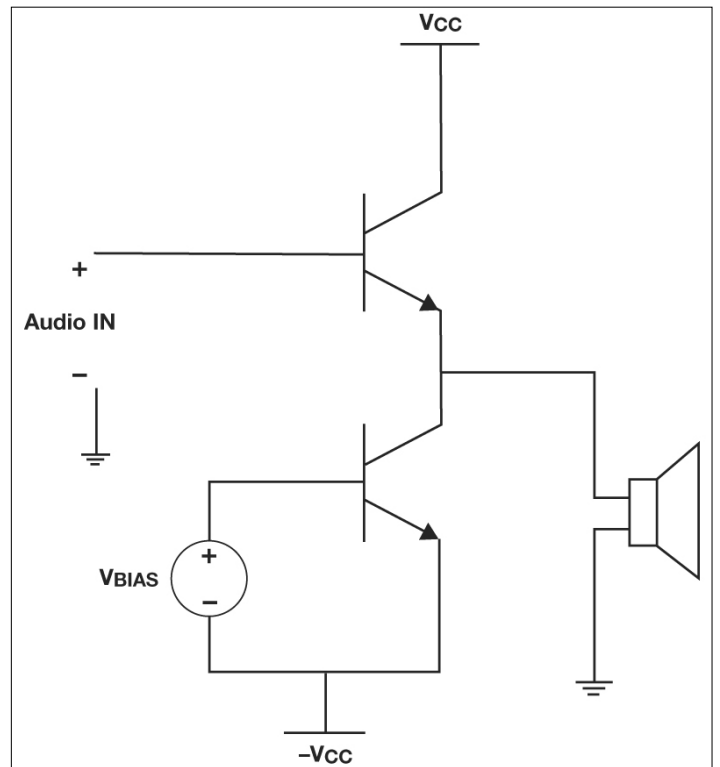


Figure 2: Typical Class A output stage

designed in a CMOS process. Due to the biasing of the output stage, efficiency will slightly suffer compared to Class B. This is visible when very low power is provided to the load, but the few milliwatts sunk won't significantly impact battery life. In the following sections, we deal with the output power capability with a single lithium/ion battery. (We will not take into account biasing power dedicated to Class AB efficiency.)

The 78.5% maximum theoretical value calculated for Class

B topology is based on the assumption of a maximum output voltage equal to the battery voltage. In a real case, the output voltage will be limited due to the saturation current and R_{DS(ON)} characteristics of the output MOS transistors. That's the reason why a maximum of 70% is reached in case of some devices driving an 8Ω load (Figure 4).

When looking at Figure 1, given the power supply, the load and the output power, the dissipated power by each amplifier is as following. We assume in

the following section, the input signal is a sine wave signal with a T period.

$$P_{OUT} = \frac{V_{OUTPK}^2}{2 \cdot RL} \text{ and}$$

$$P_{SUPPLY} = \frac{2}{T} \int_0^{T/2} V_P \cdot I_P(t) \cdot dt$$

(equation3.gif)βnot included in article

Due to the Bridge Tied Load structure when a single power supply is used, IP(t), the current provided by the battery, is a sine wave signal with a

$$\frac{T}{2} \text{ period and } \frac{V_{OUTPK}}{RL} \text{ its magnitude value,}$$

(equation4.gif)βnot included in article

Thus the link between PD and POUT (described in Figure 5) is:

$$P_D = \frac{\sqrt{2 \cdot RL \cdot P_{OUT}}}{RL} \cdot \left(\frac{2 \cdot V_P}{\pi} - \frac{\sqrt{2 \cdot RL \cdot P_{OUT}}}{RL} \right)$$

(equation5.gif)βnot included in article

As an example, if we consider typical values used in a mobile phone with RL = 8Ω and VP = 3.6V (typical lithium-ion battery voltage), the dissipated power and efficiency curves versus output power are shown in Figures 4 and 5.

With a best case efficiency of less than 70% on the output power range, the battery life can be severely limited if the product is used for music playback or gaming where the audio is playing for extended periods. In addition, the junction temperature also increases significantly under the same conditions. This curve is based on a thermal resistance from junction to air at 110 deg. C/W, which is a typical value for a 9-pin Flip Chip package

With multimedia applications using two 8 Ω loudspeakers, the

average output power is 100 to 200mW though the junction temperature is 35 deg. C higher than ambient.

Filterless Class D may be the way to go

In addition to the existing Class AB audio family with devices, there is a Class D filterless product line that brings a significant benefit to this efficiency issue with still superior audio performances.

The NCP2820 mono filterless Class D amplifier's THD+N floor is below 0.1%, with PSRR at -65dB, and it is capable of providing 2.65W into a 4Ω BTL load. Figure 6 shows a simplified schematic of a stereo system using two NCP2820 devices. Due to the filterless connection between the amplifier's outputs and the loudspeaker, using this Class D solution doesn't bring added cost in terms of external components

Efficiency is the main benefit of Class D amplification and a part like the NCP2820 is among the best-in-class regarding this parameter with up to 90% as shown in Figure 4. From 50mW up to 600mW, which covers 92% of the operating range, the NCP2820 efficiency is higher than 80%, when Class AB gives a linear growth 20% up to 70% on the same output power window. Switching losses can be neglected compared to conduction ones. RP is the overall parasitic resistance for the combined metal interconnects, lead frame and PCB traces. RON is the PMOS and NMOS resistance.

$$P_D = (2R_{ON} + R_P) \cdot I_{OUT}^2$$

$$P_{OUT} = RL \cdot I_{OUT}^2$$

$$\text{And so, } P_D = \frac{2R_{ON} + R_P}{RL} \cdot P_{OUT}$$

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A few years ago, the mobile audio amp only had to power

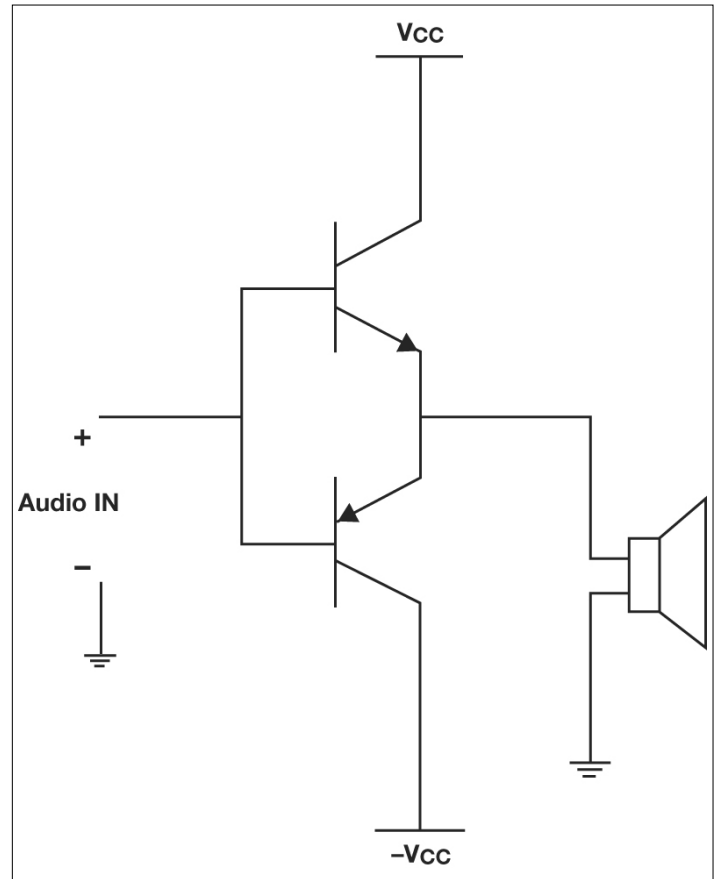


Figure 3: Typical Class B output stage

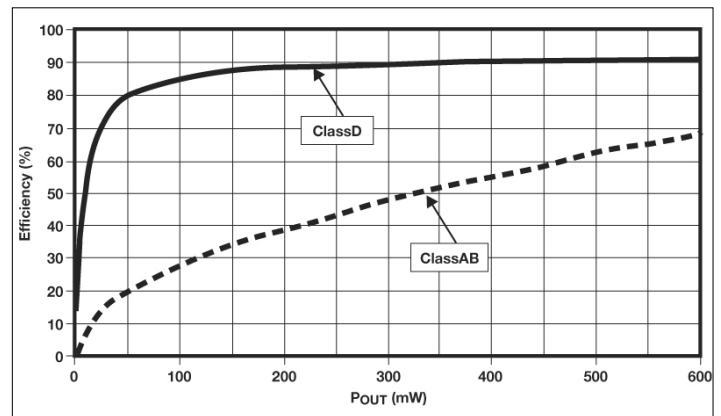


Figure 4: Class AB versus Class D Efficiency (%) versus POUT (mW) @ VP = 3.6V, RL = 8Ω

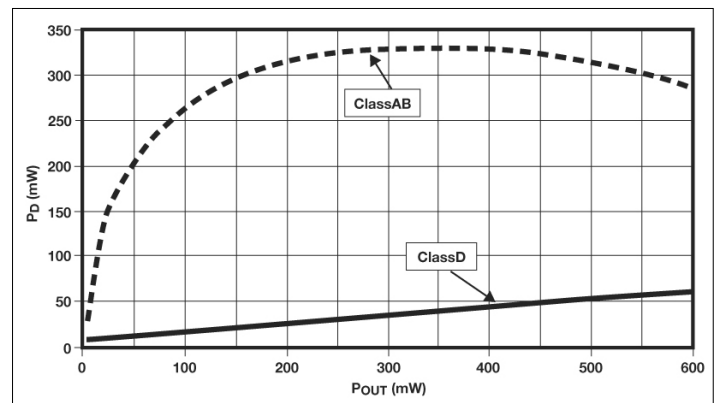


Figure 5: Class AB versus Class D Pd (mW) versus POUT (mW) @ VP = 3.6V, RL = 8Ω

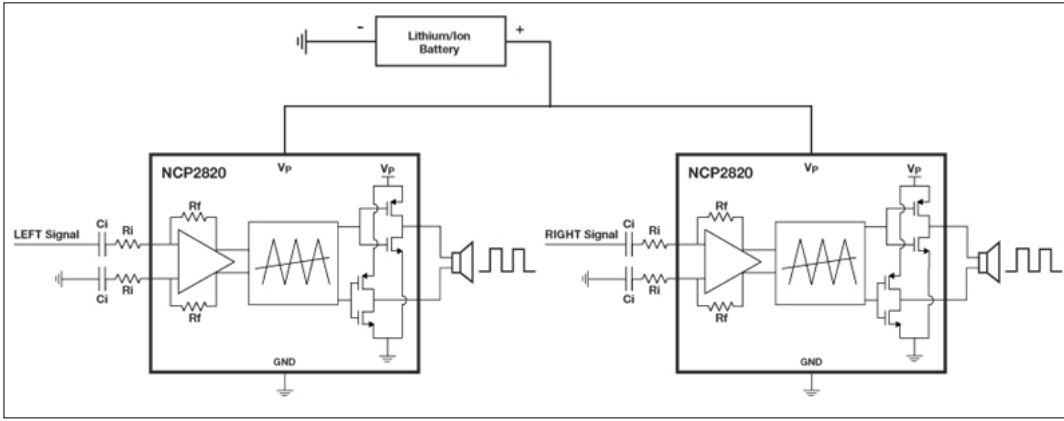


Figure 6: Stereo schematic with ClassD solution

the speaker in receive mode where the average power output was much less than 100 mW and the audio block was not a major battery power consumer. With the advent of polyphonic ringers and new multimedia applications the average audio power is several hundred mW into two loudspeakers and the duty cycle or audio use time has increased. Figures 5 and 6

show the big benefit of a Class D solution compared to a Class AB. Regarding power saving, for 300mW on each output, 600mW of dissipated power will be saved, which will have a big impact on the battery life. In addition the temperature of each Class D audio amplifier increases by a mere 4 deg.C versus the 35 deg.C increase of the Class AB design. The reduction of internal power

dissipation within the phone also has a positive impact on overall system reliability. Overall, the development of high performance Class D audio amplifiers is a key enabler for integrating advanced multimedia audio capabilities without compromising the overall power budget.

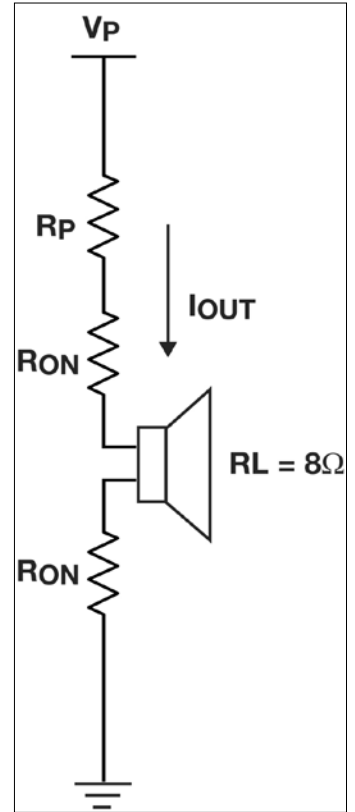


Figure 7: Resistive losses in the NCP2820 output stage