How DA7210 maximises both headphone playback time and audio performance

White Paper

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Abstract
Recent years have witnessed a huge expansion in the market for portable devices with hi-fi audio playback capability such as MP3 players, multimedia phones and hand-held games consoles. The two key requirements for audio components in these devices are power consumption and audio quality. Usually these devices are used with headphones, therefore the power consumption and audio quality *at typical headphone power levels* is of particular relevance. The move to advanced CMOS processes has driven down the power of the others blocks such as DSP and DACs; leaving the headphone, which has to drive output load, as the main contributor to overall battery life in MP3 playback.

Introduction
What is a typical headphone power level? Sound level is measured in dB SPL (decibels sound pressure level). 100 dB SPL is loud, for example shouting at close range or a jackhammer at one meter. 70 dB SPL can be considered a moderate volume level, normal conversations are around this level. The amount of power required to produce a specific sound pressure at the ear depends on the efficiency of the headphones which are usually between 95dB SPL/mW and 120dB SPL/mW. Typical in ear headphones have an efficiency of around 106dB SPL/mW. This means that 1mW of electrical power delivered to the headphone will produce 106dB SPL. With these headphones only 0.25mW would be required to produce a loud sound (100dB SPL) and just 0.25uW to produce a moderate sound (70dB SPL). It follows that for extended playback time in battery operated devices engineers should concentrate on reducing circuit power consumption at output power levels in the region of 0.25uW to 0.25mW.

Separate Headphone Supplies
Historically, one of the audio playback circuits that consumed the most power, was the headphone amplifier. This circuit is usually included on the audio DAC IC. The de facto solution has been a Class AB amplifier powered directly from the IC supply voltage. In an attempt to improve efficiency a limited number of Class D headphone amplifiers have made it to the market. However, a Class D solution creates major EMI problems and requires an LC filter as the headphone lead acts as a good antenna for broadcasting the high frequency energies produced by the Class D amplifier. Furthermore, the unknown headphone cordlength makes filter design very difficult. Even if the EMI problems can be mitigated, the fact remains that Class D amplifiers

tend not to be very efficient for load powers less than about 10mW. A more sensible solution is to use a Class AB amplifier powered from an efficiently generated low supply voltage. This supply voltage can be generated to track the required output volume level. This technique of modulating the supply voltage with a finite number of discrete steps is called Class G.

Class G headphone drivers

Providing 0.25mW per channel requires little voltage; only tens of milliVolts into a typical headphone impedance of 32 ohm. Therefore, the key to an efficient design is an amplifier that can run off a very low supply voltage. This supply voltage can be generated from an inductive buck converter but this requires a low ESR and therefore a bulky inductor, which adds cost and area. An alternative is to deploy a charge pump to generate multiple voltage levels. Small external capacitors in the microfarad range are sufficient to supplying sufficient power for this headphone driver application. For example the stereo headphone amplifier for the Dialog DA7210 runs off an integrated charge pump capable of generating both positive and negative supplies from an external 1.8V supply. An envelope tracking algorithm ensures that even on the occasions when the amplifier requires more headroom the charge pump automatically switches to a higher supply voltage; in total four positive and negative supply levels are available. Under real usage conditions, the amplifier typically runs from an internally generated +/- 0.5V for the majority of the time, but for loud passages or increased volume levels the higher supply voltages ensure that plenty of power can be delivered to the headphones without introducing distortion, clipping or saturation. The key to extending playback time is a very low quiescent power headphone driver and chargepump combination which itself may react to sudden peaks in signal amplitude with a very fast attack time.

To demonstrate the efficiency advantage of Class G over standard Class AB headphone drivers a series of measurements were setup using Dialog's DA7210 2.5mW ultra low power codec with Class G true ground headphone driver. The 2.5mW refers to the minimum power consumption of this codec, which is in DAC playback mode when supplying a headphone load.

This audio codec may be supplied from an external supply in the range 1.8-2.5V and from this single supply efficiently generates a total of four positive and four negative Class G levels using an integrated chargepump. The chargepump provides the supply to the headphone amplifiers. By setting a control register the chargepump can be forced into fixed supply mode i.e Class AB operation, with some subsequent increase in power consumption.

By charging a large (2 farad) capacitor to supply the whole codec, the capacitor voltage can be monitored as music is played into a headphone load. The rate of voltage discharge of the supply capacitor is proportional to the rate of energy consumption whilst playing music.

By repeating the measurement with the same piece of music, at the same volume level, and with the capacitor discharged between exactly the same voltage thresholds in either case then a realistic comparison between Class AB and Class G operation can be determined.

A screengrab of this setup is shown below. The voltage meter and discharge is shown in the left hand panes, on the bottom right pane the oscilloscope shows one headphone channel output (blue) and the corresponding Class G positive rail (red). The timers capture the supply capacitor discharge from approximately 2.1V to 1.85V.

Fig1: Screenshot of Dialog’s DA7210 Class G-ClassAB discharge demo suite

The Class G advantage

The measurements demonstrated a significant improvement in playback time of Class G over Class AB. The improvement varied with different genres of music with differing crest factors; mellow classical pieces showed a 2-2.5x improvement whilst rock music was lower at 1.5-2x. More about crest factors later.

This very significant advantage of Class G was only realisable because the whole DAC playback signal chain of Dialog’s DA7210 codec has been power optimised; extremely low 2.5mW quiescent current and optimally generated Class G levels combine to deliver enhanced efficiency in the sub milliwatt output power range per headphone channel. Although the Class G topology has been known for some time, when carefully applied to the headphone audio playback channel very significant improvements in playback time may be achieved versus more traditional topologies.

Audio Quality

Audio quality is our second important consideration. Consumers expect top quality audio; any audible hiss due to a high level of noise is not acceptable. The peak SNR quoted by manufactures is of little relevance to the quality experienced when using headphones as the signal levels are much smaller than the full scale levels (about 1Vrms) used to calculate peak SNR.

To quantify the audio performance into headphones we need measure the output noise again *at typical headphone volume settings*. The volume setting a user selects will depend on the crest factor of the audio content. The crest factor is the ratio of the peak signal level to the average signal level. This tends to vary from 20dB, for classical music, to 5dB for highly compressed modern music. To achieve a signal level of 89mV rms, when listening to music with a crest factor of 10dB, the volume control needs to be set such that the peak signal level will be 0.28V (10dB higher). For a typical portable audio volume control this corresponds to a volume setting of -14dB. In this scenario the end user will set the volume control to around -14dB when listening at average signal level of 89mV rms to music with a crest factor of 10dB.

The DA7210's DAC to headphone path provides class leading noise levels across the volume range. At 0dB an SNR of 99dB is achieved making it a true hi-fi quality source for home hi-fi applications, such as MP3 docking stations. Line outputs with SNR of 102dB are also available. When the volume is reduced for headphone usage the noise voltage is also reduced.

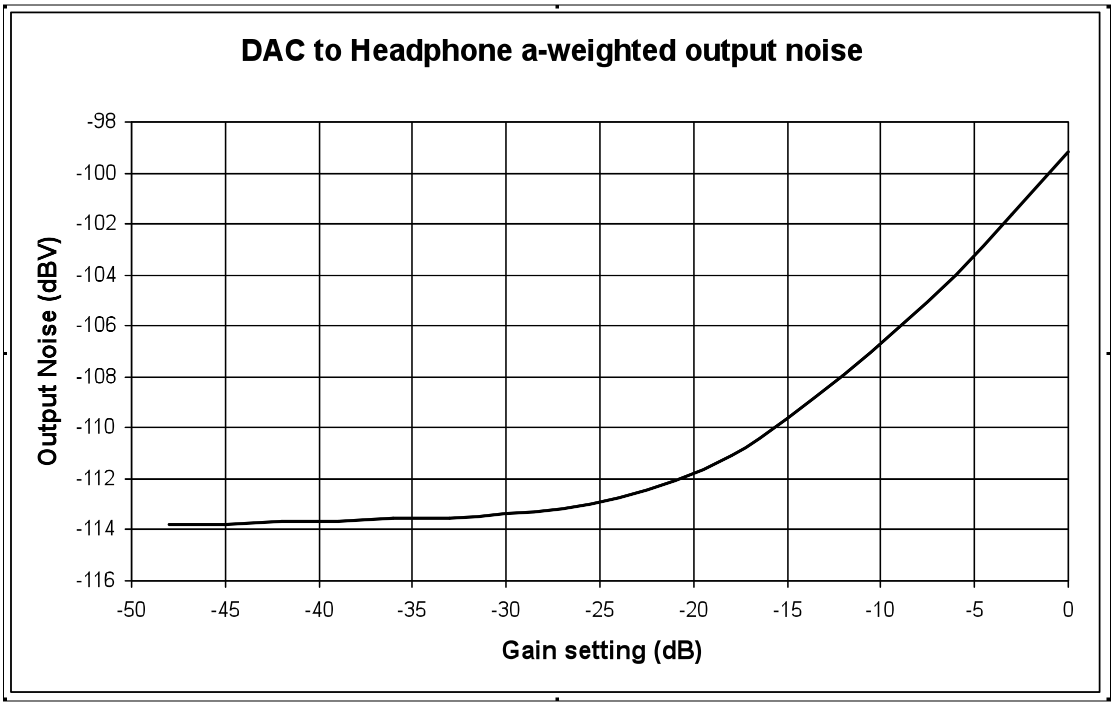

Fig 2: Headphone output noise versus channel gain setting

Headphone amplifiers often require a series resistor and capacitor combination at their output to maintain stability into a headphone load. The headphone transducer has an impedance that increases with frequency, this causes instability in some headphone amplifiers. The traditional solution is to add a capacitor/resistor network to the output of the amplifier to compensate for the rising impedance of the headphone load. These networks are sometimes called Zobel networks or Boucherot cells. The network consists of discrete components external to the IC, due to the capacitor being too large to be integrated on silicon (typically 0.1uF). DA7210's headphone amplifier does not require this network, saving valuable board space and cost.

DA7210 also provides the other features that would be expected from a modern portable audio codec, high PSRR, good clock jitter rejection, ground centred headphone output, pop and click free, low out of band noise. The combination of features and performance make it the perfect solution for the next generation smart phones and media players.

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