APPLICATION NOTE

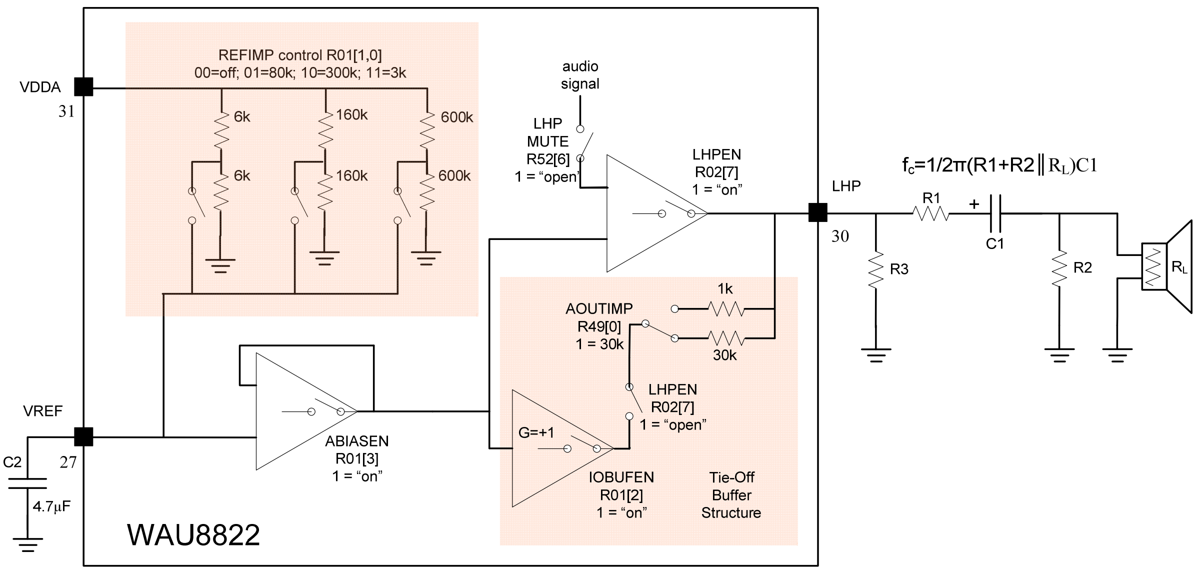
AC Coupled Headphone Output Design

Audio Codec

Headphone outputs are often required to work in a wide range of configurations. These include connection to a many different possible loads, accidental connection to other signal sources, and short circuits to ground. This application note provides general guidance about how to optimize a headphone output to achieve good audio quality, minimum to inaudible pop/click performance, and robustness over a wide range of end-user applications.

1. Headphone Output Overview

The diagram below shows a typical recommended external component arrangement, and also, the DC biasing framework internal to the WAU8822. It is important to understand the DC biasing as to avoid pop/click issues during power-up, power-down, and normal operating circumstances. For simplicity, this diagram shows only the left headphone output.



WAU8822 HEADPHONE DRIVER DC BIASING FOR TYPICAL CONFIGURATION

2. Headphone Output Structure

The above drawing shows a general topology that can cover many different application scenarios. Only the DC blocking capacitor, C1, is required. The other external components may be included for various optimizations.

2.1. Output Attenuator Concept and Benefits

An output attenuator consisting of R1 and R2 has is recommended for almost every application and headphone driver device. Benefits of the output attenuator include:

1. Maximize signal-to-noise ratio by operating codec to operate at maximum undistorted levels Attenuator reduces maximum acoustic output to be within desired sound levels.
2. Limits maximum possible output to desired operating limits, regardless of software
3. Increases immunity to external wrong-connections and ESD events
4. Increases immunity to external RF noise such as GSM radio noise
5. Balances output power to be more equal across a wide range of possible load impedances
6. Reduces output capacitor C1 size by a significant factor for same performance
7. Reduces or completely eliminating pop and click sounds by slowing/reducing voltage changes
8. Greater line level output level (working into high impedance load) while maintaining desired maximum headphone loudness owing to attenuation working into the low impedance headphone load

2.2. Output Attenuator Configuration and Calculation

Most of the output attenuator benefits are conferred by R1. R2 should be added to guarantee a DC path to ground for charging/discharging C1. This is needed when the external load is high impedance or AC-coupled, such as when connected to an external amplifier. R2 may also be chosen as to limit the maximum output in cases in which a high impedance load is used instead of the normal expected low impedance headphone load.

R3 is typically not used. It is needed only for unusual no-power or sleep conditions in which it is desired to guarantee a discharge path for C1. This can be useful to manage pop/click situations by allowing C1 to be in a known discharged state at the next system power-on event.

The system designer can determine the optimum attenuation factor by considering the maximum possible output from the WAU8822 and the maximum desired in the output device. The combined effects of R1 and R2 (if used) and the load resistance (R_L) should be such that the maximum unattenuated output of the WAU8822 will achieve the maximum desired output level in the load device or output transducer.

Design Example #1: If the maximum output of the WA8822 is 1.0Vrms and the desired maximum output into a 32-ohm load is 0.5Vrms, then an attenuation factor of 2x is desired. Thus, a series resistance of 32-ohms could be chosen for R1. With R1 = 32-ohms, the same circuit will deliver almost the same power into either a 16-ohm load or a 32-ohm load. Also, the required size of C1 is now only ½ what it would otherwise be if the output was directly connected to a 32-ohm load. In a line level application, there will be no 32-ohm load, and therefore, the maximum output level will be 1.0Vrms (instead of 0.5Vrms), which is better for line level signals.

Design Example #2: Considering further the case of Design Example #1, it may desirable to have a guaranteed DC path to ground for C1, if the load is unknown. By choosing R2 at around 120-ohms, good overall performance can be achieved without changing the other benefits of the attenuator. R2 also reduces pop/click sounds by making a voltage divider with the AOUTIMP tie-off resistor. R3 can be added to insure C1 can discharge during power-off sequencing. Both R2 and R3 are optional, if component count must be minimized.

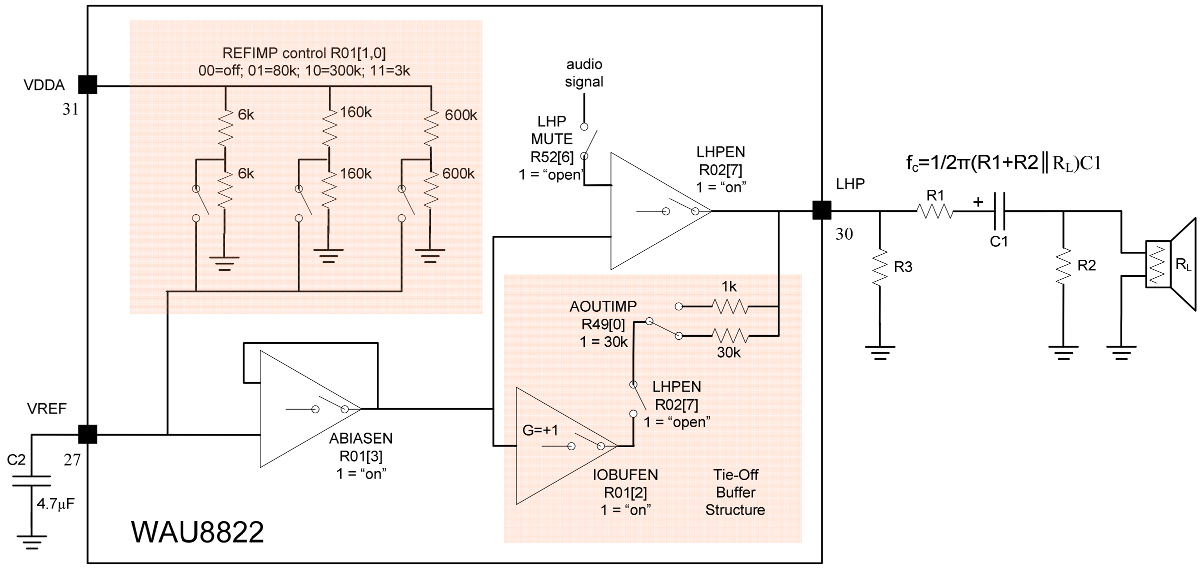
Generic Design Example: For an overall balanced design, the following values would represent an example of a system design suitable for a wide range of possible external load requirements:

R1 = 24-ohms

R2 = 120-ohms

C1 = 100µF (for 30Hz -3dB point with 32-ohm headphone and net 20-ohm series resistance)

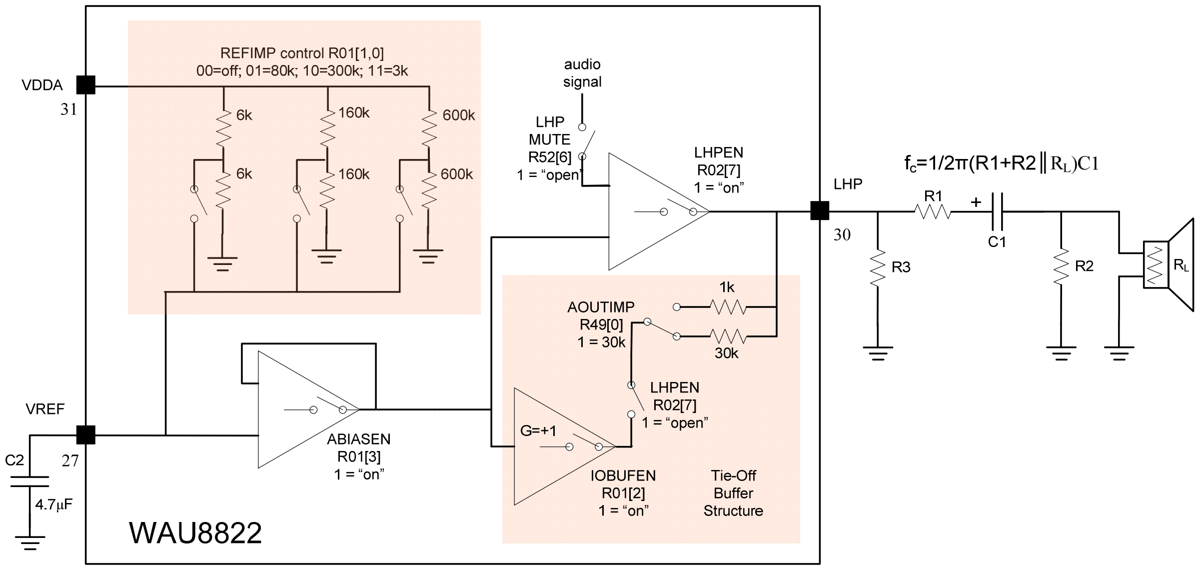
R3 = not used in most applications



WAU8822 HEADPHONE DRIVER DC BIASING FOR TYPICAL CONFIGURATION

3. Pop and Click Management

The biggest challenge in AC-coupled designs is to achieve smooth charging and discharging of the DC blocking capacitors under all power-on, operating, and power-off conditions. As a general rule, the goal is to charge these capacitors after power-on, and then keep them in the charged condition during all normal operating and sleep conditions. Because all paths are AC-coupled, this can be achieved at very low power levels. Only the "deep sleep" and power-off conditions would normally require discharging the DC blocking capacitors.



WAU8822 HEADPHONE DRIVER DC BIASING FOR TYPICAL CONFIGURATION

3.1. General Pop and Click Management Strategy

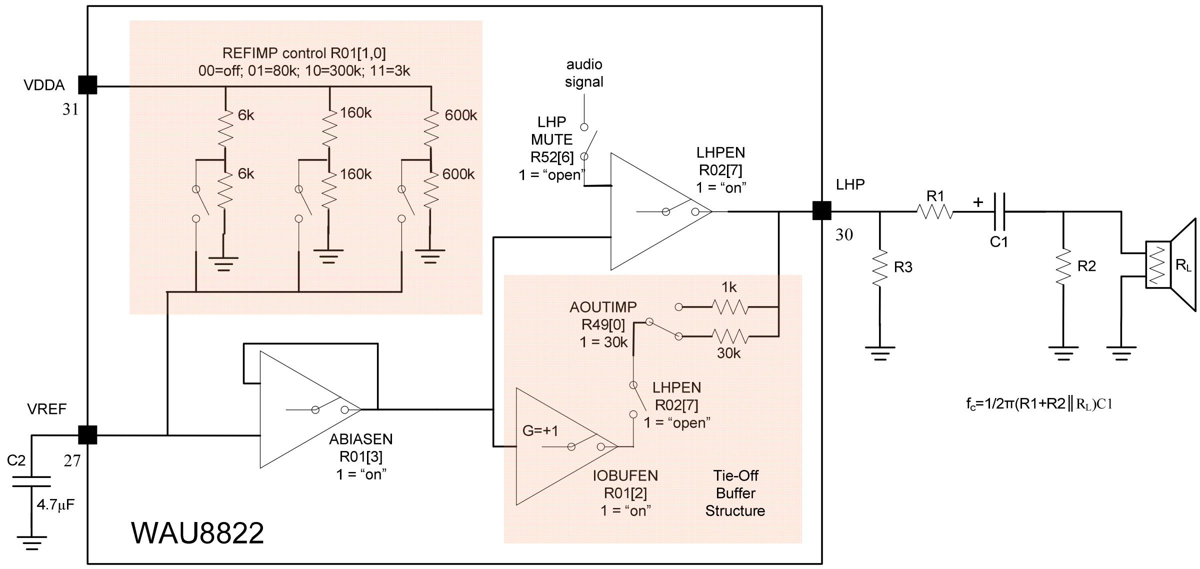
Again referring to the same drawing above, a pop or click noise will happen any time there is a sudden flow of current through C1. The IOBUFEN tie-off buffer is provided as a way to charge C1 without any pop or click noise. After enabling IOBUFEN, C1 can be charged via a series resistor inside the WAU8822 controlled by AOUTIMP. This resistor is used to charge C1 slowly to its final operating charge. After this slow charging is completed, the headphone can then be turned on using LHPEN. At this time, the headphone driver output has the same DC output voltage level as the tie-off buffer driver. Therefore, no current will flow through C1 when the headphone driver is turned on, and there will be no pop or click noise.

3.2. General Pop and Click Management Power-On Sequence

1. The strategy for minimizing pops and clicks will depend on the circuit design and application scenario. This is a general example of how to manage pop and click noises from output DC coupling capacitors.
2. Starting condition = WAU8822 power-on reset, and all capacitors discharged
3. Set WAU8822 R06 = 0x000 to use MCLK as its clock source, and not the PLL. An active MCLK is necessary for the headphone output buffer registers to be updated. If this cannot happen, the headphone gain setting and MUTE will not happen until a later time when MCLK is started. This will increase possible pop/click sounds both during this start-up sequence, and when MCLK starts running.
4. MUTE headphone, but keep headphone (LHPEN) disabled.
5. Set tie-off buffer AOUTIMP = 30k-ohm
6. MUTE headphone, set headphone to -20dB attenuation, but keep headphone (LHPEN) disabled.
7. Enable IOBUFEN and ABIASEN. There will be a small click because IOBUFEN cannot be completely zero volts output. Smaller values of R2 and R_L will minimize the click noise passing through AOUTIMP.

3.3. General Pop and Click Management Strategy (continued.)

8. Wait at least one RC time period: R = 30k-ohm; C = C1
9. Set REFIMP control for 80k-ohm impedance. This will start charging Vref at a rate that is similar in speed to the charging rate for the output capacitor, C1.
10. If possible, wait for up to about 10x RC periods for slow charging of C1.
11. If 10x RC time is not possible, faster charging can happen by changing AOUTIMP = 1k-ohm. This will make a click depending on the size of R2 and RL,and the voltage difference between the tie-off output and the charge state of C1. It is generally better to switch to 1k-ohm (if necessary) soon after starting to charge Vref at the 80k-ohm rate.
12. If faster charging time is desired, it may also be possible to change the Vref REFIMP value to the fastest impedance setting of 3k-ohm. This should be done only after changing AOUTIMP = 1k-ohm, and waiting a minimum of about one RC time after changing REFIMP to 1k-ohm.
13. After the optimum charging strategy has been completed, the headphone outputs (LPHEN in the example) can be enabled. However, it the headphone amplifier should remain in MUTE condition.
14. At this time, all of the other internal functions of the WAU8822 can be configured.
15. Next, the headphone outputs can be un-MUTED. If desired, the headphone outputs can start in a reduced volume setting, and then increased to the final output volume desired. This aspect will be heavily application dependent. The goal of this application note is to reach the point at which the headphone output can be started and un-MUTED without any pop or click noise.
16. For power-off conditions, R3 may sometimes be helpful. This normally would be a high value such as 100k-ohm. This will insure that C1 can have a discharge path to achieve zero volts after some time. For most applications, it is preferred not to have R3.



WAU8822 HEADPHONE DRIVER DC BIASING FOR TYPICAL CONFIGURATION nuvoTon

3.1. Version History

VERSION	DATE	PAGE	DESCRIPTION
1.0	February 2008		- Preliminary Revision