AND9953/D

Class D Amplifiers of LC823455 Series for Audio Applications

ON Semiconductor®

www.onsemi.com

APPLICATION NOTE

arm

Introduction

This application note describes Class D Amplifiers (called D−AMP hereafter) guideline to support customers to control D−AMP in their application correctly.

Intended audience is customers who are building audio application using LC823455 Series (called LC823455 hereafter).

BACKGROUND

D−AMP Structure

LC823455 has two D−AMP for L channel and R channel internally. D−AMP is composed of DAC and AMP as shown in Figure 1. DAC is mainly composed of Interpolator, Delta−Sigma Modulator and PWM Generator.

Regarding the DAC part, sampling frequency (Fs) of input signal increases 8 times by Interpolator and 3 times by sample & hold logic. After that, this signal can be transferred to Delta−Sigma Modulator.

Delta−Sigma Modulator also has 9 levels or 17 levels for quantization, and it is processed with timing based on 24Fs. PWM Generator generates a PWM signal with 1 bit width based on Delta−Sigma Modulator output and its period is 1/24Fs.

The AMP part is a dedicated I/O buffer for D−AMP and it employs an impedance control function while turning on or off.

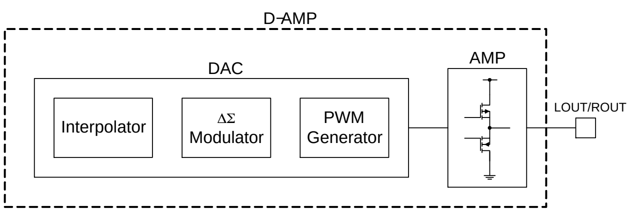

Figure 1. D−AMP Block Diagram

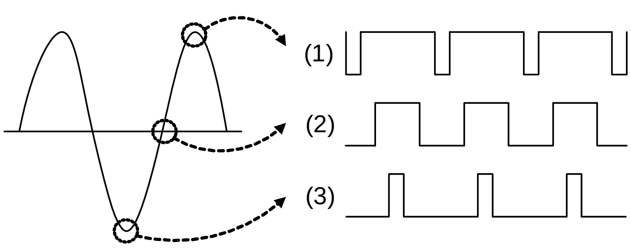

Figure 2. PWM Generation

Figure 2 shows characteristic of the PWM signal. DAC works to generate the PWM signal showing that high level code like the top part of the sine wave is converted so that high level of the PWM continues for long time such as (1), middle level code like the middle part of the sine wave is converted so that the duty of the PWM is around 50: 50 such as (2) and low level code like the low part of the sine wave is converted so that low level of the PWM continues for long time such as (3). Delta−Sigma Modulator causes this modulation.

D−AMP GUIDELINE

Need of LCR Filter

A PWM signal generated from each LOUT/ROUT terminal needs to be passed through an external LCR filter. If the LCR filter is not connected to LOUT/ROUT externally, the speaker connected directly to LOUT/ROUT terminal will be damaged strongly or may be broken because the PWM signal has strong power spectrum at around 24 Fs (1.0584 MHz if Fs is 44.1 kHz) and its overtone especially. Therefore, the LCR filter has to be connected to LOUT/ROUT directly and externally to cut off the frequency over the audible range.

Structure of LCR Filter

Figure 3 shows a LCR filter in case of Single−End form. Single−End form is a general form and it needs a 220 uF coupling capacitor to each channel. It is suitable for stereo sound, or monaural sound using only L channel.

Figure 4 shows a LCR filter in case of BTL form. BTL form generates an audio signal at one channel and the inverse of the audio signal at the other channel. Therefore, voltage amplitude at headphone for BTL form will be twice as high as Single−End form. Then, it doesn't need any coupling capacitor, but it is only suitable for monaural sound.

LCR filter which is composed of resistor Rd, inductor L and capacitor C is connected to each LOUT/ROUT terminal

October, 2019 − Rev. 1

Publication Order Number:
AND9953/D

directly in Figure 3 or 4. After this filter, PWM signal will be an analog audio signal.

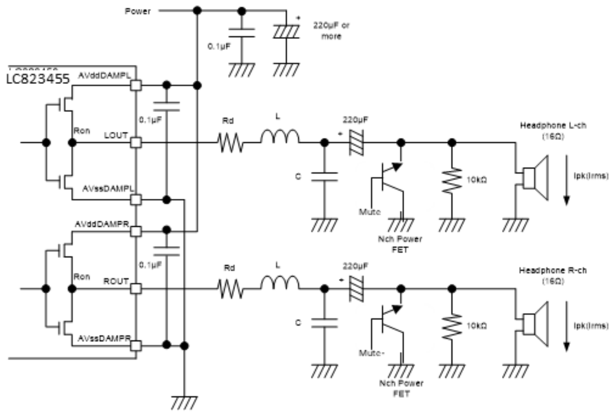

Figure 3. Single−End Form

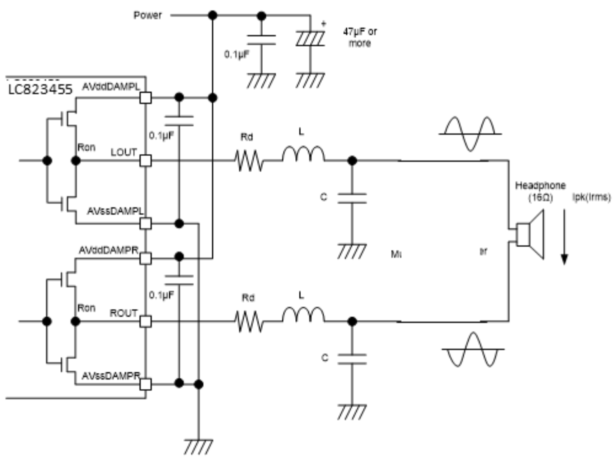

Figure 4. BTL Form

Table 1 shows an example of LCR filter parameters for Single−End form and BTL form. Regarding Rd, if its value is large, it can reduce Q factor of LCR filter, but it also reduces output gain of D−AMP. The filter of Type A in Table 1 can select 0 Ω for resistor Rd. In this case, the filter will hardly reduce output gain in the audible range, but 220 µH for inductor L requires large size physically. The filter of Type B in Table 1 can use 47 µH L of which physical size is small, but it can't select 0 Ω Rd because Q factor of the LCR filter in this case is too high. Therefore, several Ω Rd needs to be used in the filter of Type B to reduce the Q factor. The filter of Type B will be suitable for small size inductor system.

In fact, value of Rd needs to be chosen to fit the actual system, and it needs to be determined considering parasitic resistance of L. This table is an example for the guideline. You must adjust the parameters of LCR filter according to the actual system. In addition, LC823455EVK which is an evaluation board made by ON semiconductor uses an LCR filter parameter which is 47 µH L, 1 µF capacitor C and 4.7 Ω Rd because inductor L has around 2 Ω parasitic resistance.

Table 1. EXAMPLE OF LCR FILTER PARAMETER

LCR Filter	L (µH)	C (µF)	Rd (Ω)
Type A	220	0.22	0 − 10
Type B	47	1	5 − 10

NOTE: Rd doesn't include parasitic resistance of L.

Reduction of Pumping Phenomenon

Pumping phenomenon shows that power supply voltage supplied for the power supply terminals of D−AMP rises up a little when the audio signal at the headphone swings to negative voltage. It occurs especially in case of Single−End form.

As shown in Figure 5, when the headphone swings to negative voltage, LOUT/ROUT terminal generates a signal of which high level period (t1) is shorter than low level period (t2). In this case, P−ch Tr of D−AMP is switched on for the period of t1 to generate high level output. Then high level output creates the negative current (IL) of the inductor which flows into the LOUT/ROUT terminal due to a self−induction action of the inductor. This current will flow into the regulator through the P−ch Tr of D−AMP. If the regulator doesn¿t have ability to sink current, the output voltage (Va) of the regulator will rise up according to sound loudness of the headphone. Moreover, pumping phenomenon is easy to occur at very low frequency sound like several tens of Hz in the audible range because of negative swing for long time. In addition, shakes of the power supply voltage by pumping phenomenon will cause distortion of the audio signal on audio characteristics.

Therefore, it is the fact that, the value of capacitor Cd for power supply is an important parameter. 220 µF or more Cd needs to be set to D−AMP power supply terminals in case of Single−End form to reduce fluctuation of power supply voltage by pumping phenomenon.

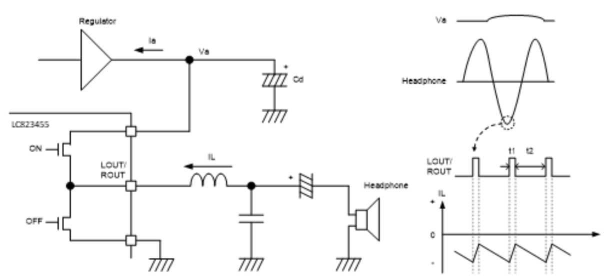

Figure 5. Pumping Phenomenon

On the other hand, in case of BTL, Ia of BTL is smaller than that of Single−End. Therefore you can use smaller value of the capacitor Cd than that of Single−End form. For example, the capacitor Cd of 47 µF or more is suitable for BTL form.

Reduction of Pop Noise

The AMP part of D−AMP has an impedance control function as shown in Figure 6. This function is controlled so that the impedance of D−AMP buffer can be decreased from OFF(Hi−z) state (0x00000) to ON state (0x3FF00) when D−AMP turns on and can be increased from ON state (0x3FF00) to OFF(Hi−z) state (0x00000) when it turns off. Then, the normal operation works in ON state (0x3FF00).

This function is available to reduce pop noise which occurs at mute state when D−AMP turns on or off.

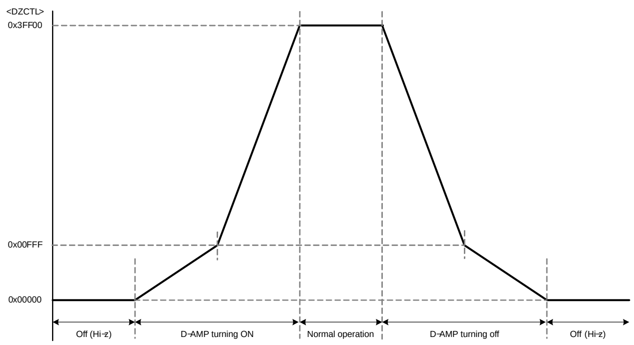

Figure 6. Hi−z Control by Impedance Control Function

Figure 7 shows simple circuit and waveform of pop noise reduction for Single−End form. Case 1 is a case that D−AMP Buffer has no impedance control function. When D−AMP turns on, the PWM signal will soon be output to LOUT/ROUT terminal (a). Then, the voltage level at (b) will rise up to 1/2 Vdd according to the time constant of L and C, and the voltage level at (c) will go to the ground level according to the time constant of Cp and headphone resistance after it rises up to ΔV1. ΔV1 will be higher because the voltage level at (b) soon go to 1/2 Vdd.

Case 2 is a case that D−AMP Buffer has the impedance control function. When D−AMP turns on, the PWM signal will slowly be generated decreasing the impedance of D−AMP Buffer according to Figure 6 (a). Then, the voltage level at (b) will also slowly rise up to 1/2 Vdd, and the voltage level at (c) will also slowly rise up to ΔV2 and go to the ground level. ΔV2 will be lower because the voltage level at (b) go to 1/2 Vdd very slowly.

Pop noise are generally caused by transient voltage across the resistance of headphone. Therefore level of pop noise depends on values of ΔV1 and ΔV2. ΔV2 is very lower than ΔV1 since D−AMP Buffer has the impedance control function.

In addition, you can add mute−TR as shown in Figure 3 to reduce pop noise further. In order to prevent a sudden change in the voltage of (c), the gate of the mute−TR should be controlled by a GPIO of LC823455 by two following steps: (1) Continue to turn on the mute−TR until the voltage of (c) becomes zeros, and (2) when the voltage in (b) becomes constant, turn the Mute−TR off.

In case of BTL form, the difference between the voltage levels at LOUT and ROUT is small, However the components of LCR filter also have variation of the values which are the cause of high difference between the voltage levels of LOUT and ROUT. Therefore the impedance control function is also necessary for BTL form.

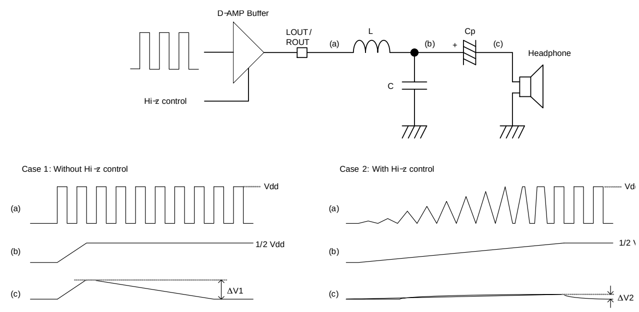

Figure 7. Pop Noise Reduction for Single−End Form

Calculation of Electric Power Supplied to Headphone

Figure 8 shows simple calculation of electric power supplied to headphone at 0 dB full scale. It is estimated simply under the condition below.

- Resistance of inductor and capacitor can be ignored.
- Maximum voltage amplitude of PWM is 90% to D−AMP power supply.

For example in case of following conditions:

- Configuration is set as Figure 8
- Ron is 2 Ω
- Rd resistor is 0 Ω and headphone resistance RL is 16 Ω
- Power supplied to headphone at 0 dB full scale.

The P can be calculated and its result will be 7.2 mW in case of Single−End form, and 23.3 mW in BTL form. Then, in this case, efficiency of power conversion: H is 88.89% in Single−End form and 80.0% in BTL form.

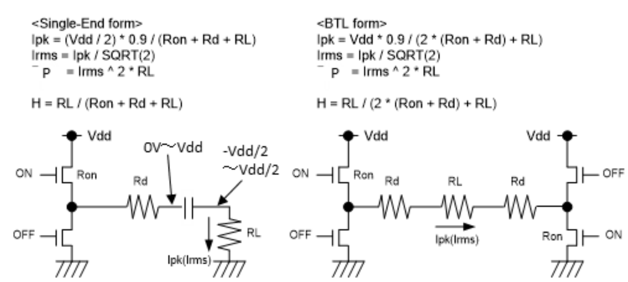

Figure 8. Model for Power Supplied to Headphone

The Arm logo is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative