Design of Mobile Digital Stereo Amplifier System using TPA2008D2 & Secondary Battery

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Abstract: Existing audio power amplifiers do not satisfy the requirement of recent digital products such as PMP and MP3 that requires mobility and miniaturization, because of large volume due to high power, and inconvenient transfer to direct connection back of power supply. To solve these problems, we designed class-D digital stereo amplifier to use TI 's TPA2008D2, which power dissipation and low caloric value. The second lithium ion polymer battery is applied and implemented for low electric power and high effectiveness mobile digital audio system. Designed digital audio system can fill up the battery through power adapter and USB port. We passed through efficient circuit pattern design process and analysis experiment about inside noise for stable digital audio system design. Also, we could improve the reliability of product development by using 3D digital amplifier circuit, which is applicable to mobile digital audio system design.

1. Introduction

Audio amplifier can divide class according to topology of electrical output efficiency, distortion factor, linearity and THD(Total Harmonic Distortion) etc. We can categorize the audio amplifier into 4 basic types; class-A, B, AB and D type. Generally analog amplifier's efficiency is low and size is too big because of heat-sink. By these reasons, analog amplifier is not suitable to mobile IT devices such as MP3, DVD and PMP. On the other hand, class-D amplifier's ideal efficiency is up to 100%. It has various advantages, for example its THD, heat ratio and noise are very lower level than any other types. And its size is very compactable apt to mobile IT devices. In this study, a design and implementation method for digital stereo amplifier system including secondary battery is proposed. TPA2008D2 is Digital-to-Digital Converter that changes and amplifies in digital without flowing analog conversion to solve analog amplifier's problems. Li-Polymer battery is applied for mobility and PCM(Protection Circuit Module) is designed. And also, 3D design method is applied for pcb pattern design and prototype modeling. In figure 1, basic concept of digital amplifier is shown as block diagram.

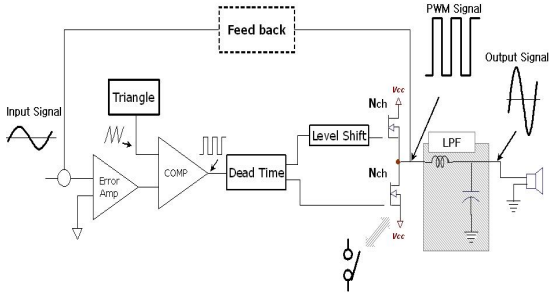


Figure 1. Block diagram of digital amplifier

2. Design of Digital Stereo Amplifier

Class-D amplifier is displaying near efficiency for 100%, and characteristic of frequency response is super-duper, and there are advantages that distortion factor and noise is less. Compared triangle waveform in comparator with analog input signal is changed to PWM signal. The changed signal is created by digital PWM signal that is amplified via dead time and level shifting. Amplified PWM signal is changed to analog signal by low pass filter (LPF) which is placed at front of speaker. The sound source is amplified and reconstructed through the system. And Li-Polymer battery which is applied for mobility is charged by battery charger of PCM. The total system that is including digital amplifier and PCM is shown in figure 2 as block diagram. In this paper, designed digital stereo amplifier using TPA2008D2 of TI improves its dynamic characteristic and gets lower pcb pattern noise than other class-A, B, and AB amplifiers. Circuit schematic diagram is designed using CSiEDA's WINPCB which is electronic circuit design tool for the designed digital amplifier. For compact design and mobility, we designed and integrated class-D digital stereo amplifier and Li-Polymer battery PCM circuits. The designed system can supply power and charge a battery both AC adapter and USB port. And also, sound source is supplied using USB port and direct input port. These design concept and functions are very helpful for mobile IT devices users.

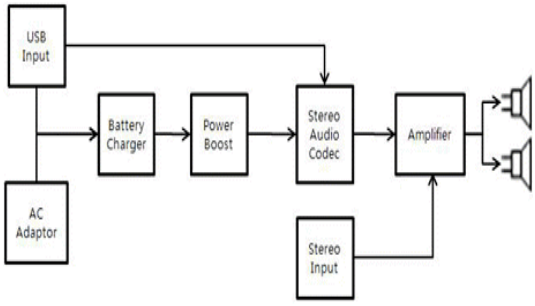


Figure 2. Block diagram of mobile digital stereo amplifier system using PCM

Figure 3 is schematic diagram of digital amplifier that use TPA2008D2 of DDC mode. When electric current passes

to conductor of pcb pattern or power cable, strong noise may be produced. Because of this point, we must design circuit pattern maximum shortly.

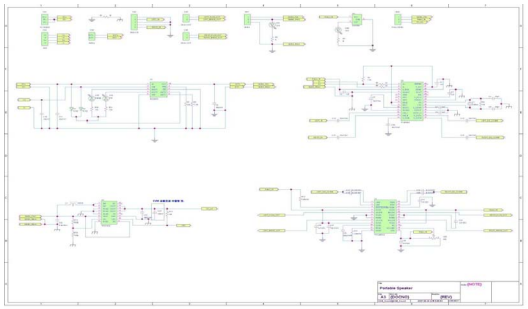


Figure 2. Schematic diagram of digital amplifier

3D pcb pattern diagram based on the schematic diagram using 3D function offering in design tool is shown in figure 3. There is advantage that 3D pcb composition can remove problem that can happen in manufacturing process by assembling of parts and simulation of pcb working in the advance. Figure 4 is 3D design of pcb pattern.

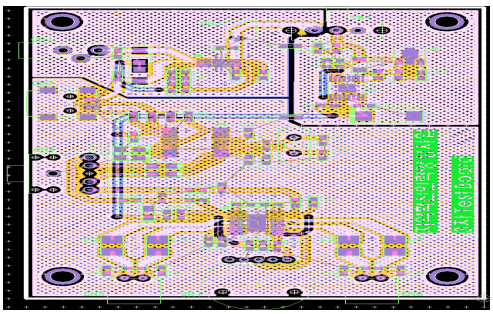


Figure 3. pcb pattern design

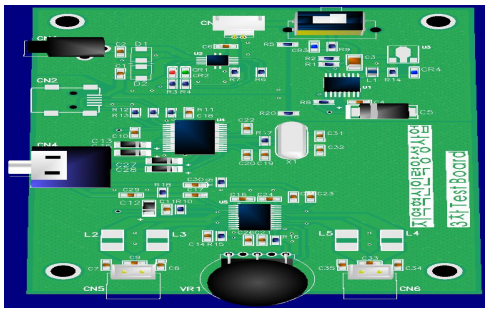


Figure 4. 3D design of pcb

Prototype model of digital stereo amplifier system is designed using Pro/Engineer Wildfire software. 3D data of the designed prototype model can be created through CSiEDA and its design schematic diagram is shown in figure 5. The external size of modeling prototype is 125 x 65 x 35mm(W x H x D). Right and left stereo speakers are designed as folder type for compact external appearance. Digital stereo amplifier and PCM is designed and integrated as one board which is placed on the center part of prototype.

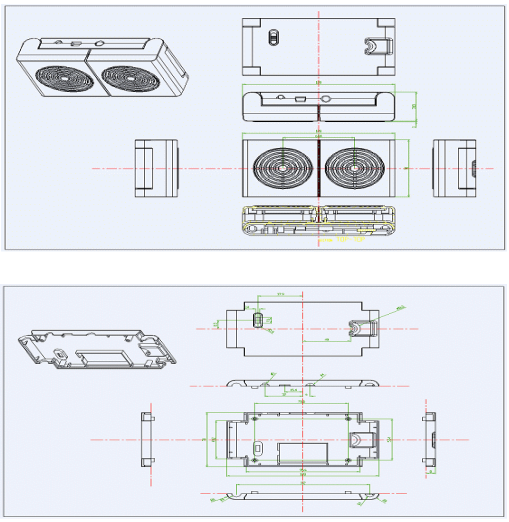


Figure 5. 3D design of prototype model

3. Design of PCM for Li-Polymer Battery

Mass of lithium polymer electric cell is half than nickel hydrogen electric cell of same mass. Also, average voltage displays effect that like connect 3 nickel hydrogen-oxygen fuel cells by series as 3.7 [V]. Because do not use heavy metals such as cadmium or mercury, can charge and discharge more than 500th in normal state. When charge or discharge is occurring, lithium polymer battery can minimize bug of electric cell because there is no memory effect that capacity decrease occurs, and has advantage that can charge in time that is early into high speed charge. Capacity test is measuring who can flow out capacity of charging electric cell by discharge. Usually decide reference voltage and ends discharge in case of reach in reference voltage. Because can not use low voltage even if discharge is so low. About, judge that discharge is completed at voltage of 3.0 [V]. Profile of secondary battery is shown in figure 6.

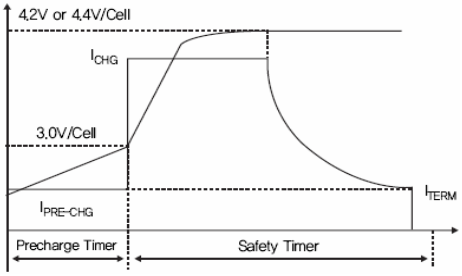


Figure 6. Profile of secondary battery

Capacity is inverse proportion in case of secondary battery has non-linear special quality by various factor, and discharge current increases. Number of times of repeat usable charge and discharge was limited. About, limit first capacity by 60%. Because internal resistance of charge condition rises by repeat cycle, capacity decrease phenomena are appeared as shown in figure 7.

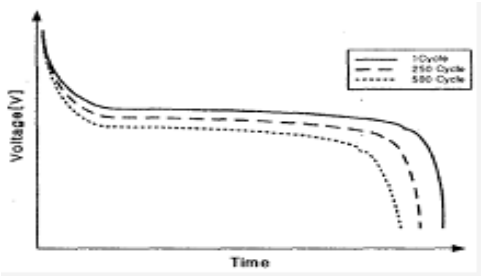


Figure 7. Cycle characteristic of secondary battery

Because electric cell contains chemical substance on inside, when leave, capacity by chemical reaction decreases. Discharge is preceded at the fast speed as temperature is high. Figure 8 shows the discharge characteristic of secondary battery.

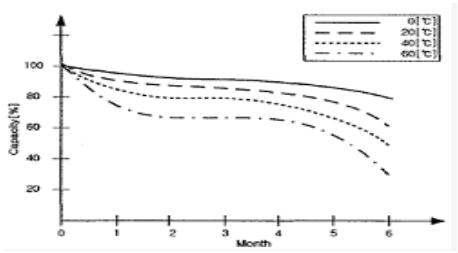


Figure 8. Discharge characteristic of secondary battery

PCM circuit schematic diagram is designed using CSiEDA's which is electronic circuit design tool for designed protection circuit module. Its schematic diagram is shown in figure 9. TI's BQ24023 chip is applied for basic PCM circuit design. BQ24023 supply two battery charge method. One is AC adapter which is basic, another is USB port. So, the presented system adopts both of two methods for user convenient.

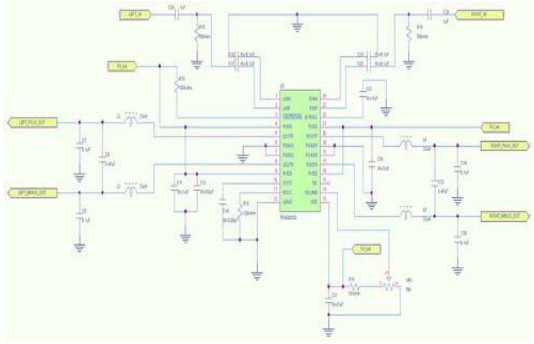


Figure 9. Schematic diagram of protection circuit module

4. Implementation and Test for designed system

For performance test including noise test, the designed system is implemented as shown in figure 10. And figure 11 is final prototype picture of designed system. As show in figure 10, all parts of system is placed in one board which is integrated digital amplifier circuits and battery charger circuits. Li-polymer battery is putted on rear side of board.

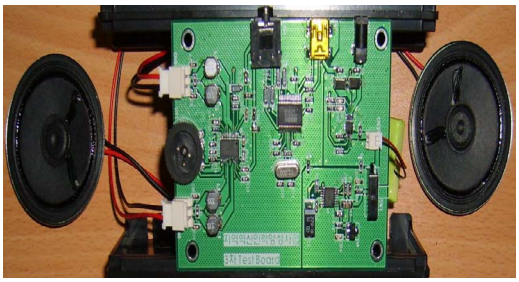
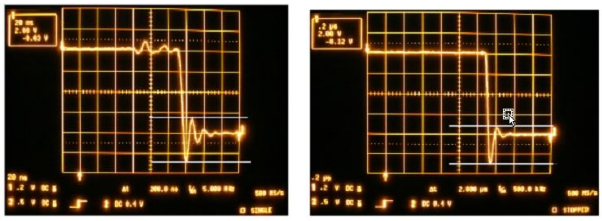


Figure 10. Test board picture of designed system

Figure 11. Prototype picture of designed system

We measured before and after waveforms of inductor application at the output stage and tested performance of digital amplifier. Measured noise from input signal of 20[KHz] can be reduced by inductor as shown in figure 12.



(a) before (b) after

Figure 12. Improvement by applying inductor

In figure 12(a) with in case of did not apply inductor , ringing phenomenon of 4.2[V] is appeared, but when applied inductor with figure 12(b), could know that ringing phenomenon is decreased by 3.6[V]. Therefore, in this paper, applied inductor to reduce this ringing phenomenon, and wished to lay length of pattern shortly by maximum and decrease effect of outside noise. Figure 13 is PWM conversion waveform of digital stereo amplifier about song sound source as input and measures amplification waveform that is reconstructed by analog signal again.

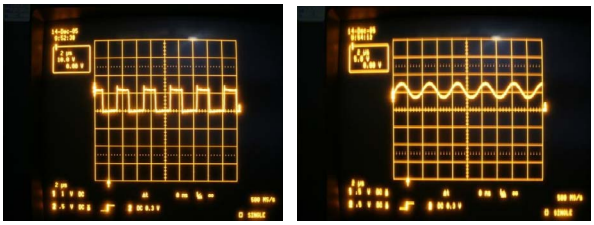


Figure 13. PWM waveform and reconstructed waveform

5. Conclusions

In this paper, mobile class-D amplifier system is designed and implemented using TPA2008D2 and PCM. Presented design method and system are suitable for multimedia and IT devices such as MP3, PMP, notebook PC and etc. Its size and external appearance are very compact and mobility is excellent. User can charge a battery through AC adapter and USB port easily. The system can reconstruct a sound from direct input port or USB port connecting to other digital devices. Experiment results, signal distortion is about 0.002%, audio quality sound is 15.6W@8Ω/10% THD+N per channel, high efficiency is 81%@15W/4Ω and dynamic range is 102dB, was expose that performance of digital stereo amplifier that is implemented on the whole is good. We passed through efficient circuit pattern design process and analysis experiment about inside noise for stable digital audio system design. Also, we could improve the reliability of product development by using 3D digital amplifier circuit, which is applicable to mobile digital audio system design.

References

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