

Design of wireless class-D stereo amplifier system using Bluetooth

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ABSTRACT

What with large volume and high power consumption, conventional audio amplifier is not suitable for recent mobile IT devices such as PMP, MP3 and notebook PC but a class-D amplifier is more appropriate for such mobile IT devices because a class-D amplifier has various advantages in digital and compact circuit design. In addition, by applying Li-polymer secondary battery and Bluetooth technology to a class-D amplifier, the system can be more portable and light. In this paper, a design and implementation method for wireless class-D stereo amplifier system is presented.

INTRODUCTION

Audio amplifier was invented in 1906 by Lee De Forest then he invented the triode vacuum tube. The triode was a three terminal device with a control grid that can modulate the flow of electrons from the filament to the plate. The triode vacuum tube amplifier was used to make the first AM radio. Since then, with development of technology, most modern audio amplifiers are based on solid state devices such as BJTs, FETs and MOSFETs. Audio amplifiers based on transistors became practical with the wide availability of inexpensive transistors in the late 1960s. The key design parameters for audio amplifiers are frequency response, gain, noise, and distortion. In general, audio amplifier is classified as A, B, AB type for analog designs and class D for switching design. Unlike class-A, B or AB amplifier, class-D amplifier shows near electrical efficiency for 100% and distortion factor and noise is very low while frequency response is super-duper. Therefore, in this paper, Texas Instruments' DDC chip which has low distortion and high electrical efficiency is used to make the most use of existent class-D type stereo amplifier system. The Li-polymer secondary battery charging system is applied for portability and convenience. In connection with, minimizing electric power consumption and protection circuit module is considered for Li-polymer secondary battery. And Bluetooth technology is used to make wireless audio system.

THEORY OF CLASS-D AMPLIFIER

The class-D amplifier uses switching to achieve very high power efficiency (more than 90% in modern designs). By allowing each output device to be either fully on or off, losses are minimized. The analog output is created by pulse-width modulation; i.e., the active element is switched on for shorter or longer intervals instead of modifying its resistor. There are more complicated switching schemes like sigma-delta modulation, to improve some performance aspects like lower distortions or better efficiency. Amplifiers can divide class according to topology of output stage and judge electrical property by efficiency, distortion factor, linearity, THD (Total Harmonic Distortion) etc. Even if class-A amplifier is no sign or load while there is no cross over THD, a lot of electric

currents are passed and happen by heat. Do not pass over maximum efficiency 25%. Because electric current flow in specification output device of class-B amplifier's output bias becomes cut-off for 1/2 cycle and efficiency is higher than class-A. Its maximum efficiency is 50%. Because class-AB amplifier suspends bias electric current to improve cross over by mode that set operating point through class-A and class-B, while efficiency drops. Table 1 is classification for digital amplifiers.

Table 1. Efficiency comparison of amplifier

Class Type	Theoretical value (%)	Practical value (%)
class-A	50	25-50
class-B	78.8	50~70
class-AB	78.5	50~70
class-D	100	90

The 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 than the others. An analog input signal is changed to PWM signal when measured against triangle waveform using comparator as shown in figure 1.

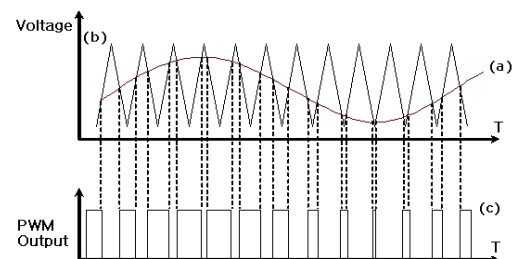


Figure 1. Signal converting to PWM

The digital PWM signal is amplified via dead time and level shift. And the amplified PWM signal is restored and displayed as analog signal flowing output LPF in front of speaker as shown in figure 2. Figure 2 is the block diagram of class-D amplifier.

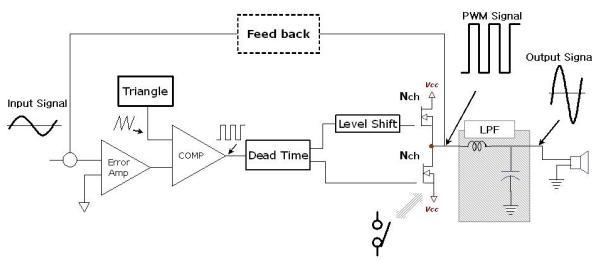


Figure 2. Block diagram of class-D amplifier

DESIGN OF THE SYSTEM

A digital audio system includes a direct current (DC) voltage supply unit generating a DC voltage from a commercial alternating current (AC) voltage; and a digital audio amplifier pulse-modulating the DC voltage using an audio signal, low-pass filtering the pulse-modulated DC voltage, and obtaining an output audio signal corresponding to the input audio signal. The class-D is much more efficient than class -AB power amplifier. As such, class-D amplifier does not need large transformer and heavy heat sink, which means that it is smaller and lighter in weight than an equivalent class-AB amplifier. All power devices in a class-D amplifier are operated in on/off mode. Output stages such as those used in pulse generators are examples of class-D amplifier. The term usually applies to devices intended to reproduce signals with a bandwidth well below the switching frequency. Li-Polymer secondary battery and Bluetooth technology are applied to the class-D amplifier to invent the proposed system. Figure 3 is block diagram of multiple & wireless class-D stereo amplifier system which is suggested in this paper.

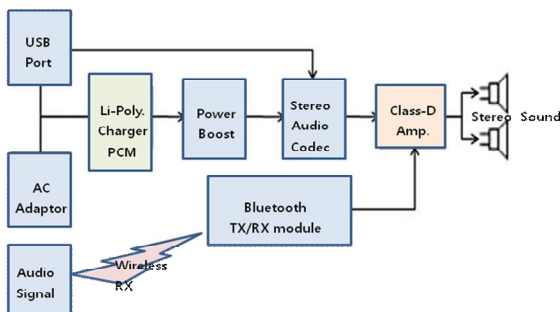


Figure 3. Block diagram of the suggested system

In this paper, Texas Instruments' TPA2008D2 which has low distortion and high electrical efficiency is used to make the most use of existent class-D type digital stereo amplifier system. The TPA2008D2 is a third generation 5V class-D amplifier from TI. The efficiency of TPA2008D2 is shown in figure 4.

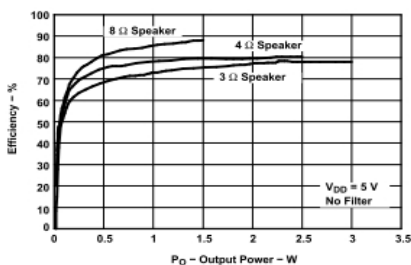


Figure 4. Efficiency of TPA2008D2

The circuit schematic diagram of multiple & wireless class-D stereo amplifier system is designed using the CSiEDA's

WINPCB which is electronic circuit design tool. Figure 5 is schematic diagram of class-D stereo amplifier module using TPA2008D2 chip set.

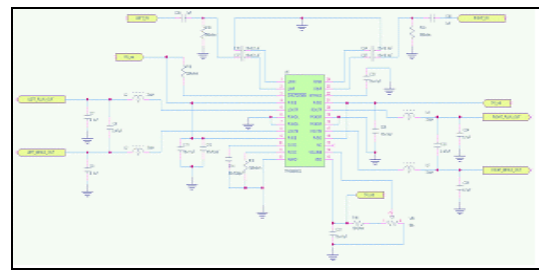


Figure 5. Schematic diagram of class-D stereo amplifier module using TPA2008D2

In general, Li-polymer secondary battery features small size, lightweight, and large capacity, which can be utilized in many portable products for a long period, such as cellular phones, camcorders, and notebook computers. But when Li-polymer secondary battery becomes overcharged, its electrolyte solution is decomposed, gas is produced, the internal pressure increases, and metal lithium is precipitated, which can cause a risk of fire or explosion. If Li-polymer secondary battery is over discharged, the electrolyte solution is decomposed causing the degradation of the battery performance. In order to prevent these problems, the use of a protection circuit is necessary. It monitors overcharging, over discharging, and over current states of Li-polymer secondary battery, and controls overall charging and discharging paths. The protection circuit module to protect Li-polymer secondary battery is suggested in this paper. Figure 6 is block diagram of general protection circuit module for Li-polymer secondary battery.

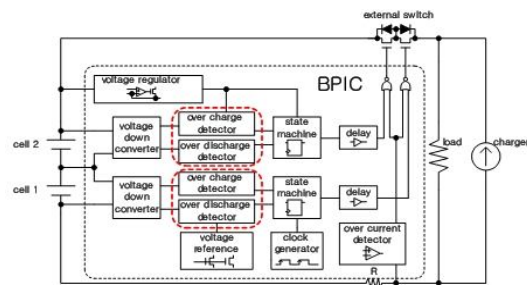


Figure 6. Block diagram of protection circuit module

Designed protection circuit module to generate charge control signal for over charge and discharge control signal for under charge characteristic of the Li-polymer secondary battery is shown as schematic diagram in figure 7.

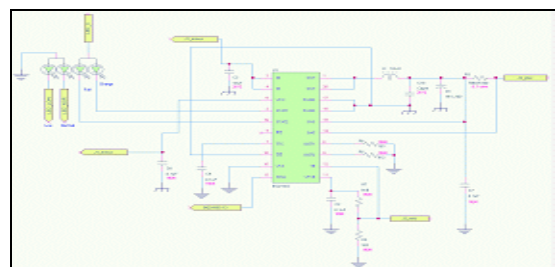


Figure 7. Schematic diagram of protection circuit module

The Bluetooth was started from concept that connected in all communication environments by single equipment integrat-

ing different communication devices. And it is short distance digital information & communication mode that employs spectrum diffusion technology of communications. Bluetooth forms ad-hoc network in extent within 10m. It is available worldwide because act in ISM(Industrial, Scientific and Medical) wide band. Bluetooth system supports point to point connection and point to multi point connection. Pico net is Bluetooth's minimum unit and in distance within master surrounding about 10m of one can connect same time to slave of maximum seven. Also, Scatter net is networking that composed connecting the Pico net. This can realize wireless connection that connects in extent about 100m. Figure.8 is Pico net & Scatter net system

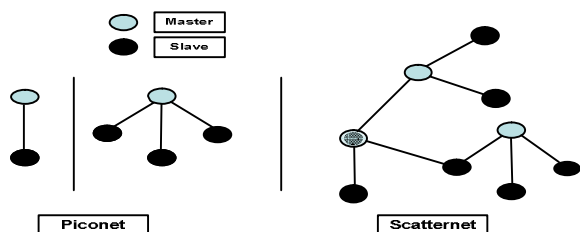


Figure 8. Pico net & Scatter net system

Paging process to communicate between Bluetooth devices is as follows. Paging unit becomes master in this connecting process and paged unit becomes slave. Master unit goes through the inquiry process while paging process. Master decides access code and frequency sequence from slave unit's Bluetooth address data.

IMPLEMENTATION OF THE SYSTEM

There are many advantages in 3D PCB pattern design method to implement an electrical circuit. In this paper, the Pro/Engineer Wildfire tool is used for this. It can optimize allocation of electrical components by decreasing spatial loss and mutual interference. For performance test, the system is designed and implemented as shown in figure 9. All modules of the system, class-D stereo amplifier module, Li-polymer secondary battery protection module and Bluetooth module, are combined into a single board with compact size.

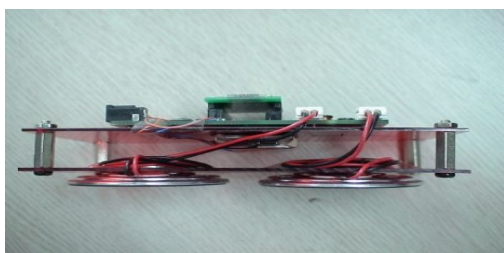


Figure 9. Test board picture of the system

An input signal is amplified to PWM conversion waveform through the system amplifier and the waveform is restored to an analog signal again as shown in figure 10.

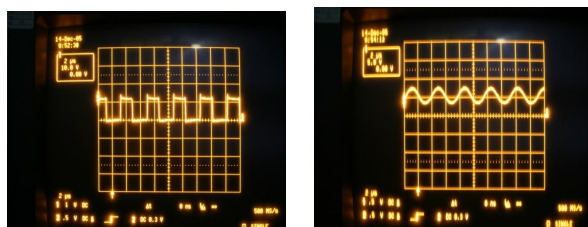


Figure 10. Amplified PWM and its restored waveform

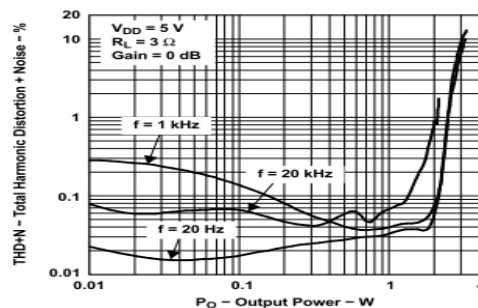


Figure 11. Electrical and operating characteristics

Figure 11 is the electrical and operating characteristics of the system. According to the figure 11, the output power is 3W at 3Ω/THD+N 10% and THD+N are 0.045% at 1.5W/1KHz, 0.3% at 2.2W/20Hz~20KHz. In connection with electrical and operating characteristics of protection circuit module, over voltage protection of the system is 4.25±0.025V, under voltage protection is 3.15±0.08V and over current protection is 1.8A.

CONCLUSIONS

In this paper, class-D stereo amplifier is implemented using Texas Instruments' TPA2008D2 which has low distortion and high electrical efficiency. The TPA2008D2 is a third generation 5V class-D amplifier from TI. The efficiency of the suggested system is 88% at 8Ω and 78% at 3 Ω. The signal distortion is about 0.002%, audio quality sound is 15W at 8Ω/10% THD+N per channel and dynamic range is 102dB. Protection circuit module is applied to operate and manage Li-polymer secondary battery. Applying protection circuit module makes the system more useful and portable. So the designed system's size and appearance are very compact and light. User can charge a battery through AC adapter and USB port easily. And to implement wireless audio system, Bluetooth technology is used in this system. Also, we could improve the reliability of the system through 3D design method. The proposed system in this paper is suitable for mobile IT device such as MP3 and PMP. And the systems' electrical and operating characteristics show good experimental results.

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