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Improved LC Filter in Class D Amplifier using Simulated Inductor

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Abstract: Class D audio power amplifiers are used to amplify the audio signal as this amplifier has the main advantage of low power dissipation. It makes use of the passive filter at the output stage to eliminate the high frequency components present in the modulated output and to get back the amplified audio signal. This passive filter makes use of inductors and capacitors. The size of the inductor becomes exceedingly large due to more number of turns required at audio frequencies. To eliminate the passive component namely the inductor used in this filter, a new technique of replacing L by the simulated L, which makes use of the active devices along with resistors and capacitors is proposed in this study. It eliminates most of the disadvantages of passive filter and gives an improved performance of the filter as well as faithful amplification from class D amplifier. The simulation is done in PSPICE and results are presented.

Key words: Simulated inductor, operational amplifier, oscillators, active tuned oscillator

INTRODUCTION

The class D audio power amplifiers are used in the frequency range of 20 to 20 kHz compared to other types of amplifiers because, the power dissipation is less as its output consists of train of positive and negative pulses due to pulse width modulation. The efficiency is around 100% (Hmida *et al*., 2007). The frequency content of the pulses includes not only the desired audio signal but also the unwanted high frequency components. A low pass LC filter is usually inserted between the output stage and the load namely the loud speaker to retrieve the audio signal. So the filter performance is very important as it decides the overall efficiency (Liu, 2007), reliability and the audio performance.

The audio signal which is to be amplified is modulated using the modulation technique namely the Pulse Width Modulation (PWM) (Berkhout and Dooper, 2010) or Pulse Density Modulation (PDM). PWM equates the input audio signal with the triangular wave of 4 kHz. This produces a train of pulses and the duty ratio is related to the amplitude of audio signal in PWM. In the pulse duration modulation, the average value of the input signal depends on the amount of pulses for a specified time duration. This modulated signal is then used to drive the driver circuit which produces the amplified output. The output consists of the modulated output which has the fundamental frequency as well as the other frequency contents. In order to extract the desired amplified audio output, LC filter is used at the output stage (Ge and Chang, 2010) as shown in Fig. 1.

The implementation of class D amplifier has many challenges and one among them is the design of filter at the output stage. The conventional method uses inductors along with the capacitors. The ideal inductor used in the LC filter is an iron core. The size and the number of turns used for the inductor makes it impractical for class D audio amplifier (Kumar *et al*., 1989) and it produces Electro Magnetic Interference (EMI). The use of inductor core results in heating and so cooling problem crops up. In this study an alternate and an efficient solution is presented.

The ideal inductor is replaced by a simulated inductor whose performance is same as that of the ideal inductor over the entire audio frequency range of operation. The inductor which is simulated using op-amp, resistors and capacitors is used in analog circuits for implementing filters which are analog (Susan and Jayalalitha, 2010a, b, 2011a, b). In this study, the simulated L used as an alternate method of implementing L and its application in class D audio amplifier is presented.

MATERIALS AND METHODS

Simulated inductor circuit: One way of implementing the simulated L is the use of active component and capacitors. The simulated L is realized from the basic Generalized Impedance Converter (GIC) (Franco, 2007) consisting of two operational amplifiers and five impedances. By properly choosing the components of the impedances, GIC is used to realize the inductor. One such circuit is the Antoniou's circuit as shown in Fig. 2. The impedance of the circuit is given by:

$$Z_{in} = \frac{V}{I} = sCR^2 \quad (1)$$

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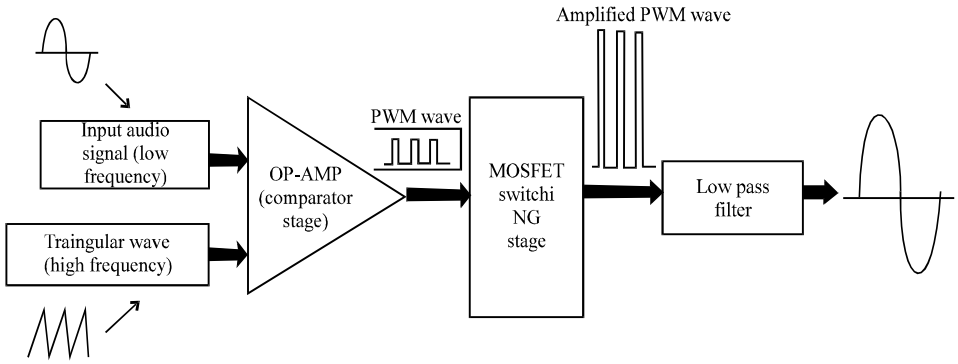

Fig. 1: Block diagram of class D audio power amplifier

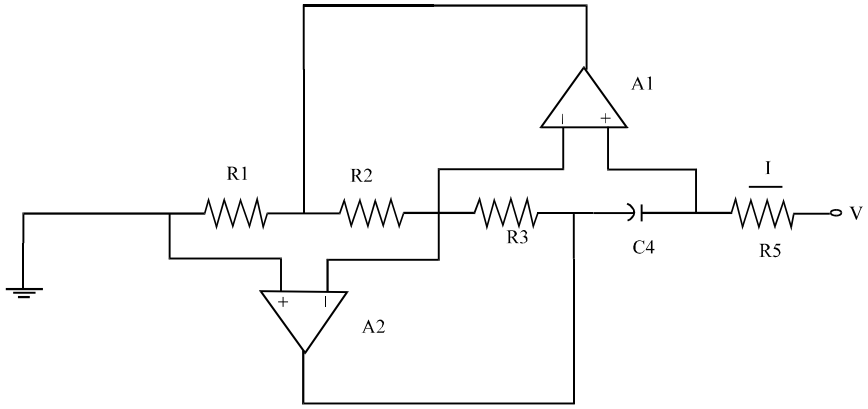

Fig. 2: Antoniou's simulated Inductor circuit for replacing the passive inductor

which represents an inductor and whose value is given by $L = CR^2$. The expression is obtained with the basic assumptions of operational amplifier. This simulated L is used for the implementation of the LC filter at the last stage of the Class D amplifier.

The complete circuit of the Class D audio amplifier along with simulated inductor and shifter circuit for phase change are shown in Fig. 3. The circuit for shifting the phase is shown in Fig. 4.

RESULTS AND DISCUSSION

Design of the complete circuit of class d audio power amplifier using simulated l: Experimental set up of class D audio amplifier with simulated inductor circuit design is follows:

Triangular wave: For f_0 = 4 kHz and $V_{0(PP)}$ = 4 V, R_1 = 330 Ω, R_2 = 330 kΩ, R_3 = 1 kΩ and C_1 = 1 μF.

Low pass filter:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

For f_0 = 100 kHz and C = 1 μF, L = 2.53 H.

Simulated inductor: $L = CR^2$ where $R_1 = R_2 = R_3 = R_5 = R$ and $C_4 = C$.

For L = 2.53 H and C = 1 μF, R = 1.592 kΩ.

Phase shifter: Phase shift θ = 90°.

$R_1 = R_2 = R_3$ = 10 kΩ, R = 159 kΩ and C = 0.01 μF.

The experimental set up is given in Fig. 5.

A sine wave of input 1 V, 500 Hz is given as one input to the comparator which is to be amplified, while the other is the triangular wave of 4 V, 4 kHz as revealed in Fig. 6. The output obtained is the Pulse Width Modulated wave which produces a train of pulses as shown in Fig. 7.

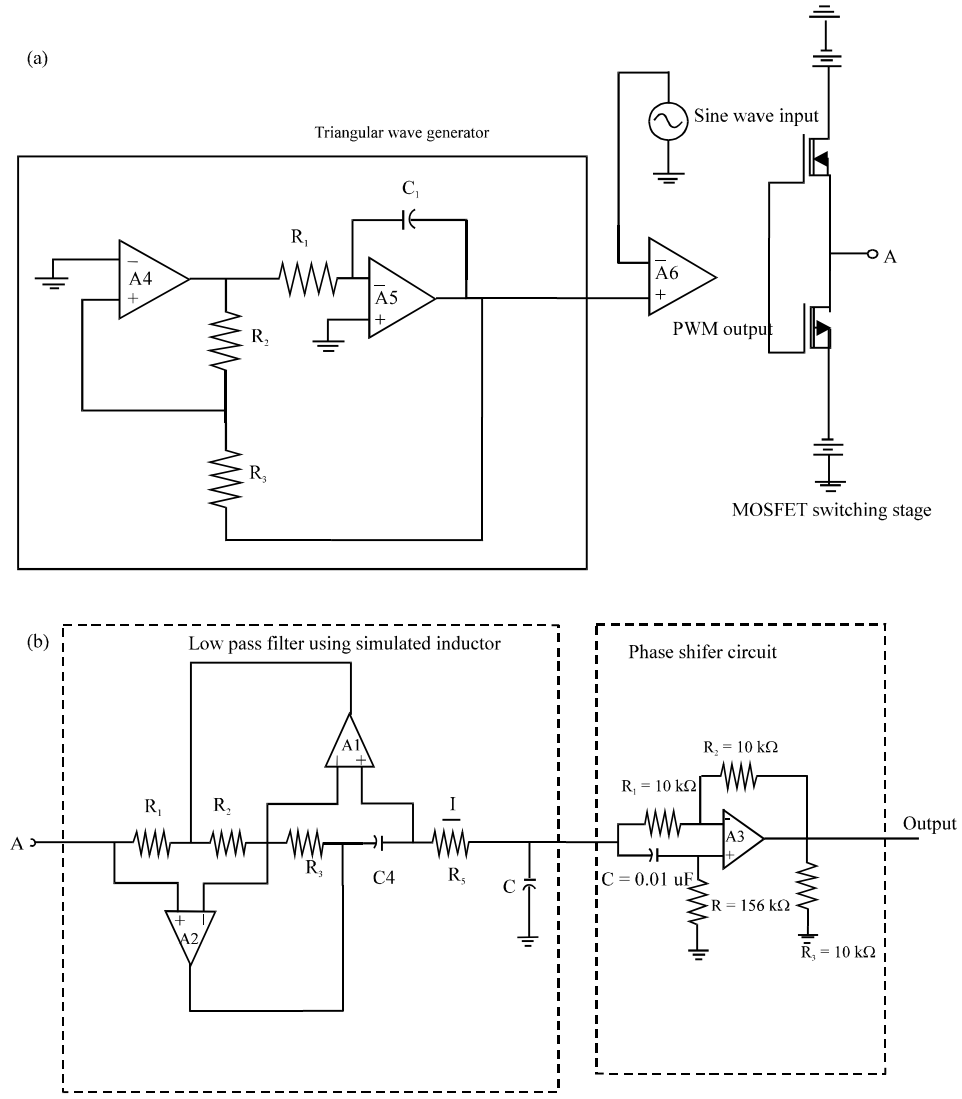

Fig. 3(a-b): Class D audio amplifier using simulated inductor circuit

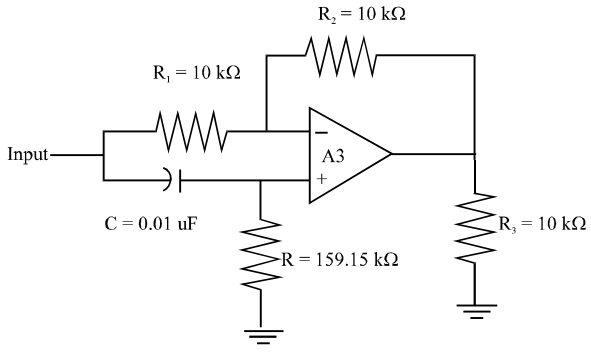

Fig. 4: Phase shifter circuit for shifting the output from low pass filter

This is given to a MOSFET switching stage via a driver circuit whose output is an amplified PWM wave. The amplified PWM wave is given to a LC low pass filter stage where the low frequency components are allowed to pass through and the high frequency components are restricted (Messghati *et al*., 2011). In the LC filter, L is substituted by the simulated L before given to the audio load, loud speaker. The simulated L is designed for the inductor value of 100 H with C = 25.33 nF. The output is an amplified version of the input along with some phase shift as displayed in Fig. 8. The shift in phase is compensated by a proper phase shifter and the phase shifted output is shown in Fig. 9.

The use of simulated inductor has the following advantages:

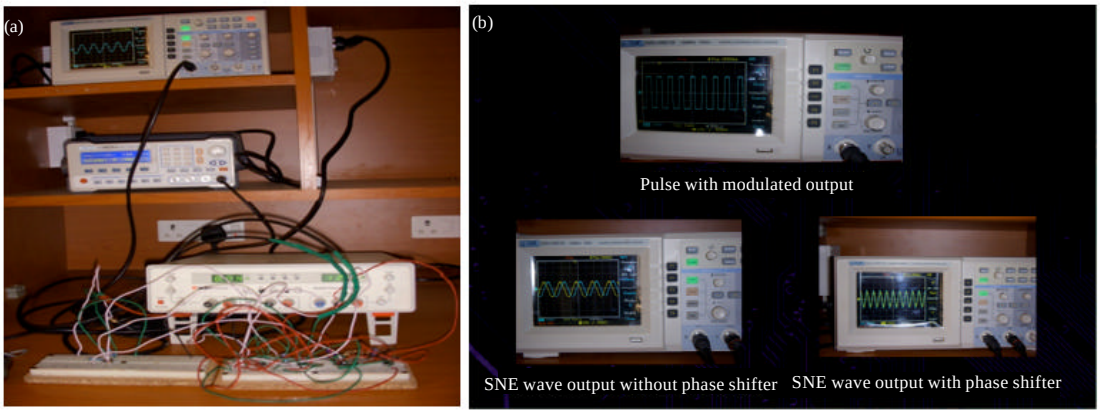

Fig. 5(a-b): Experimental set up of class D audio amplifier with simulated inductor circuit

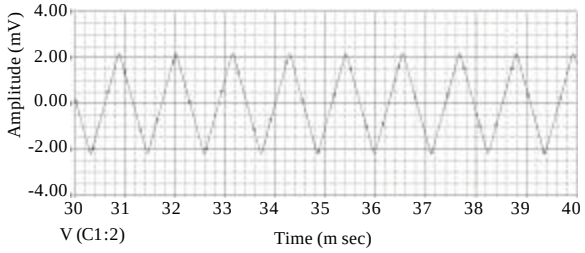

Fig. 6: Triangular wave input for the comparator

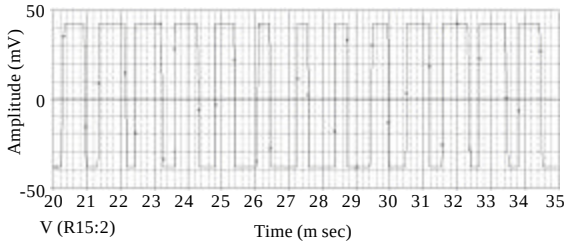

Fig. 7: PWM output at the output of the comparator

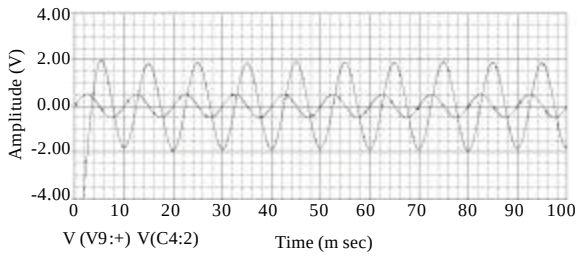

Fig. 8: Output of class D audio power amplifier without phase shifter

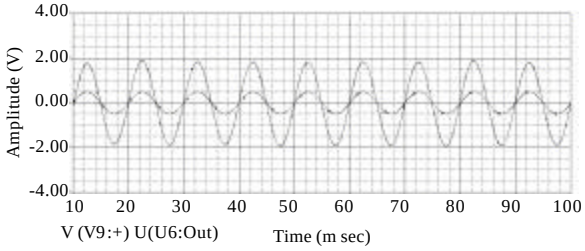

Fig. 9: Output of class D audio amplifier with phase shifter

- Eliminates the use of heavy size and more number of turns of inductor
- Avoids EMI problem (Himmelstoss and Edelmoser, 1999)
- Removes heat dissipation which is caused by the insulation resistance of the wire of the inductor
- Makes the fabrication of inductor using simulated L compatible with today's IC technology.

The advantages of a Class D amplifier are: Reduction in power loss and increased efficiency (Jeong *et al*., 1995; Chang *et al*., 2000)

CONCLUSION

The filter less class D amplifier mostly introduces some sort of distortion in the output. So; filters are used at the output stage of class D audio power amplifier. The major shortcoming of using class D audio power amplifier lies in the design of low pass filter used at last stage. It can be avoided by using simulated L which has the main

advantage of reduction in the size of inductor and its associated problems. This in turn lessens by and large the size of the amplifier. The power expenditure is minimized and cost is also trimmed down. The simulated L and the class D amplifier are designed and the results are presented.

REFERENCES

Berkhout, M. and L. Dooper, 2010. Class-D audio amplifiers in mobile applications. IEEE Trans. Circuits Syst. Regul. Pap., 57: 992-1002.

Chang, J.S., M.T. Tan, Z. Cheng and Y.C. Tong, 2000. Analysis and design of power efficient class D amplifier output stages. IEEE Trans. Circuits Syst. Fundam. Theory Appl., 47: 897-902.

Franco, S., 2007. Design with Operational Amplifiers and Analog Integrated Circuits. 2nd Edn., McGraw Hill International, USA.

Ge, T. and J.S. Chang, 2010. Filterless class D amplifiers: Power-Efficiency and power dissipation. IET Circuits Devices Syst., 4: 48-56.

Himmelstoss, F.A. and K.H. Edelmoser, 1999. Compensated Class-D amplifier as high quality AC-Voltage source. Proceedings of the IEEE International Conference on Power Electronics and Drive Systems, Volume 1, July 27-29, 1999, USA., pp: 116-120.

Hmida, G.B., H. Ghariani and M. Samet, 2007. Design of wireless power and data transmission circuits for implantable biomicrosystem. Biotechnology, 6: 153-164.

Jeong, J.H., H.H. Seong, J.H. Yi and G.H. Cho, 1995. A class D switching power amplifier with high efficiency and wide bandwidth by dual feedback loops. Proceedings of International Conference on Consumer Electronics, June 7-9, 1995, USA., pp: 428-429.

Kumar, U., S.K. Shukla and Amiete, 1989. Analytical study of inductor simulation circuits. Active Passive Electron. Comp., 13: 211-227.

Liu, Y.H., 2007. Novel modulation strategies for Class-D amplifier. IEEE Trans. Consum. Electron., 53: 987-994.

Messghati, Z., Y. Laghzizal and H. Qjidaa, 2011. Pulse width modulation for class D audio power amplifier in CMOS 0.18um process with 85% of efficiency. Proceedings of the International Conference on Communications, Computing and Control Applications, March 3-5, 2011, Hammamet, pp: 1-4.

Susan, D. and S. Jayalalitha, 2010a. Analog filters using simulated inductor. Proceedings of the 2nd International Conference on Mechanical and Electrical Technology, September 10-12, 2010, Singapore, pp: 659-662.

Susan, D. and S. Jayalalitha, 2010b. Synthesis of low pass filters using FDNR. Int. J. Electron. Electr. Eng., 3: 263-269.

Susan, D. and S. Jayalalitha, 2011a. Bessel filters using simulated inductor. Proceedings of the International Conference on Recent Advancements in Electrical, Electronics and Control Engineering, December 15-17, 2011, Sivakasi, pp: 268-271.

Susan, D. and S. Jayalalitha, 2011b. Notch filter using simulated inductor. Int. J. Eng. Sci. Technol., 3: 5126-5131.