A High Efficiency Class D Amplifier Application

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Abstract

Today, according to the recent developments in electronics, the devices are needed to be smaller and portable. Components of electronic devices need to have small dimensions and high efficiency. In this paper a Class D Amplifier is designed and applied with high efficiency and low electromagnetic interference concerns. Results are given consequently.

1. Introduction

Power amplifiers are used in order to generate high current and voltage levels in industrial test systems and applications. They can be classified as class A, B, AB, C, and D amplifiers. [7]

The class A amplifiers have simple structures. Hence the efficiency of amplifier is limited with 25% which is low for industrial applications.

The class B amplifiers have more complex structure then the class A. Therefore the efficiency of these amplifiers is about 78%. But, by using class B, in a single period half of the signal can be amplified. Thus the major disadvantage of this class amplifiers is the high degradation

Class AB amplifiers shows the properties of both class A and class B and the efficiency of this type inverters is approximately 50% In a period whole signal can be amplified. Therefore the linearity is high and the degradation is lower. Thus the class AB amplifiers are mostly preferred in applications.

Class D amplifiers work with switching structure. Therefore the efficiency of this class amplifiers are theoretically 100%. Furthermore they have small dimensions and less degradation. [3] Another advantage of class D amplifiers is to be a lower valued or a long lasting power source for devices which need lower supply current such as batteries. [4]

Class D amplifiers convert the input signal into consecutive pulses. The pulse width of the signal is much higher than the input signal. Class d amplifiers handles the switching process in higher frequency than the sound band. The switching interval of most of them are between 300 kHz and 2 MHz. [10] The clean signal is obtained by filtrating the distortion and the carrier signal inside amplified signal.[10]

Class D amplifiers are mostly used to amplify sound signals. The main areas that these amplifiers used are automotive, batteries, hearing aids and cell phones. As an example LM4673, the amplifier used in cell phones, is one of the smallest class D amplifiers with dimensions of 1.44 X 1.44 mm in micro SMD package[1,2]

2. Structure of Class D Amplifiers

Generally class D amplifiers are made of voltage comparator, class D switching part and a low-pass filter as seen in Fig. 1.[5]

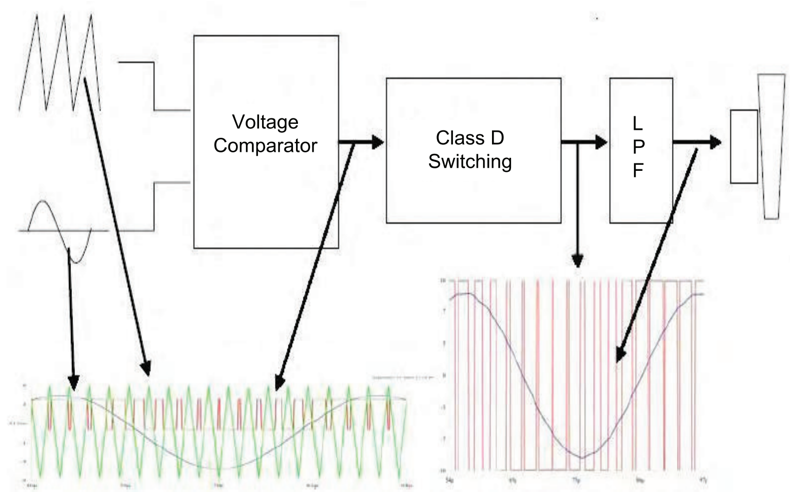

Fig. 1. The general schematic of class D amplifiers.

The most used modulation type used in class D amplifiers is Pulse Width Modulation (PWM). To generate a PWM signal, an input signal and high frequency carrier signal in order to modulate the input signal is needed [4]. This type of modulation is called "natural sampling" [6]. PWM is the control of the pulse-period ratio by comparing the input signal with a high frequency carrier signal. In this purpose, the class D amplifiers are used as switches [1]. If the transistor is in off state the current passing through it assumed to be zero. If the transistor is in on state the voltage passing through it assumed to be zero. Thereof the power losses are low and the efficiency is high. An other advantage of this situation is that there are less heating over the amplifier.

According to Nyquist sampling theorem to regain a modulated signal, component which has the highest frequency must be sampled twice with sampling frequency. The signal is low-pass filtrated to be clarified from the carrier signal in demodulation [6]. In most applications second order Butterworth transfer function is preferred in both economical and performance concerns. The inductance, L, and the capacitance, C values used in Butterworth filter can be achieved as:

$$L = \frac{R\sqrt{2}}{w_0} \quad (1)$$

$$C = \frac{1}{w_0^2 L} \quad (2)$$

In class D amplifiers mostly full-bridge inverter is used Because of lower output offset, DC blocking capacitance is not needed in full-bridge structures [8].Absentness of blocking capacitance lessens the dimensions of full-bridge. A basic full-bridge structure can be seen in Fig. 2.

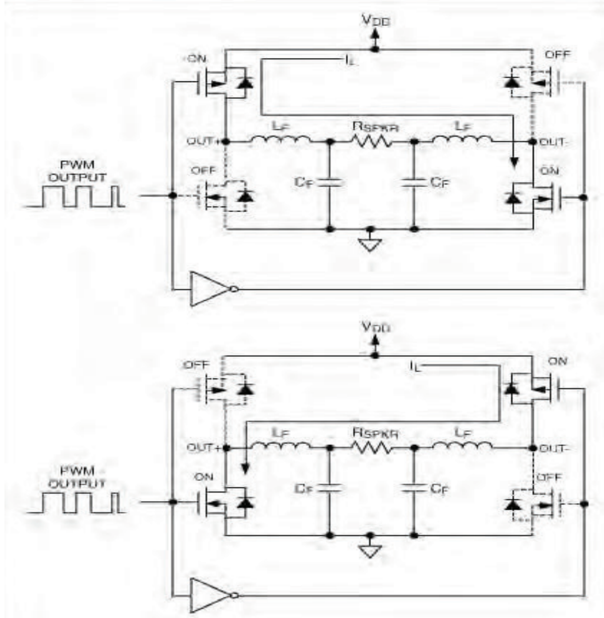

Fig. 2. The general structure of full-bridge inverter.

2. Structure of Class D Amplifiers

The system is designed as a Sonar amplifier accordingto the principles mentioned above. The extended circuit diagram of the system prepared with Proteus software can be seen in Fig. 3.

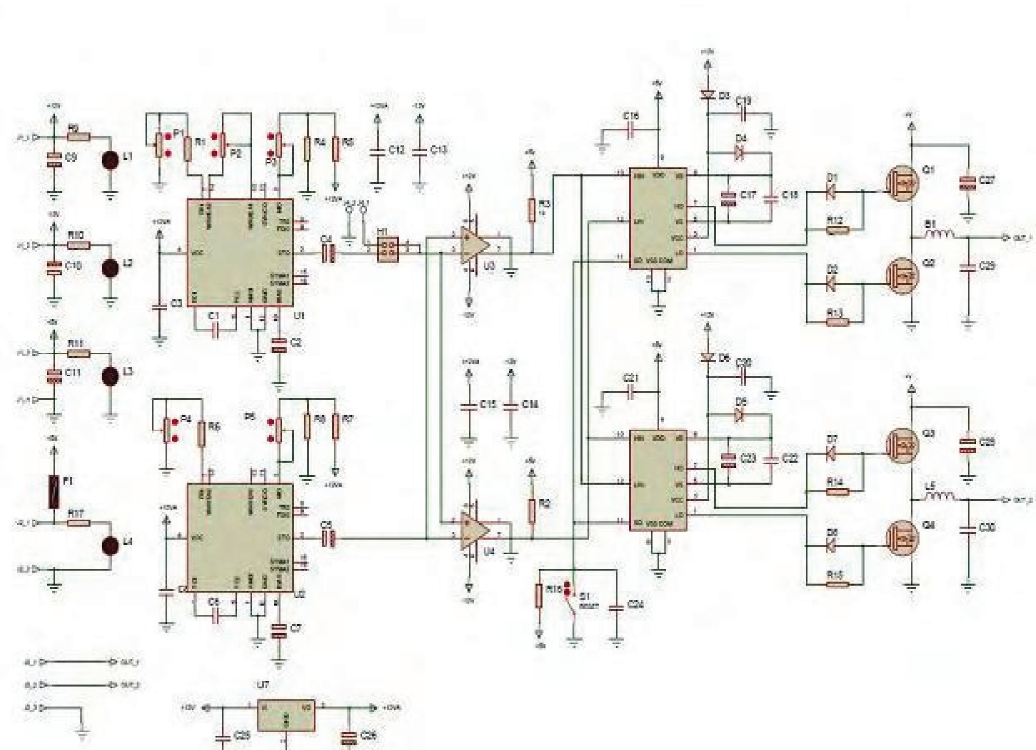

Fig. 3. Circuit diagram of application system.

The most important part of gate driver section of the application circuit is bootstrap elements. In most applications the system can operate between 10 Hz and 100 kHz levels in bootstrap mode. The bootstrap diodes (D_4, D_6) are significant for PWM applications. The settled capacitors on source, V_{cc} are used to compensate the inductance occurs in supply busses [9]. Only V_{cc} can be seen bootstrap capacitors, C_{17}, C_{18}, C_{22} and C_{23} .

The lowest bootstrap capacitor values can be calculated as:

$$C \geq \frac{2\left[2Q_g + \frac{I_{qbs(\max)}}{f} + Q_{ls} + \frac{I_{Cbs(\max)}}{f}\right]}{V_{cc} - V_f - V_{LS} - V_{Min}} \tag{3}$$

Where Q_g is the charge load of FET in high voltage side, I_{Cbs} is the leakage current of bootstrap capacitor, I_{qbs} is the maximum V_{BS} shutting current, V_f is forward voltage loss between the ends of bootstrap diode, V_{LS} is the voltage loss of the FET's ends in low voltage side, V_{Min} is the lowest voltage between V_B and V_S and Q_{ls} is the level changing load per turn (usually 5nC for 500V/600V MGD's).

If the circuit is available for design, it will be appropriate to use different capacitors. The bootstrap capacitor value must be higher than 0.47 uF [9].

The bootstrap capacitor is charged when the high side switch is off and the V_s voltage taken to the ground. The capacitor must provide this charge and hold this level voltage. Otherwise a waving over V_{BS} can occur and halt the operation of high voltage side [9]

3. Application and Results

The application system can be seen in Fig. 4.

To provide high efficiency, the circuit elements must have low losses in high frequencies and must possess a good heat stability. MOSFET's are preferred because of their high switching frequency and low losses.

The efficiency of application circuit can be calculated as:

$$\eta = \frac{P_{OUT}}{P_{IN}} x100 \tag{4}$$

where P_{OUT} and P_{IN} are output and input powers consecutively.

The effiency of the application system under different voltage levels can be seen in Tab. 1

And the input and output waveforms of the application system can be seen in Fig. 5.

According to results of application the efficiency of system is between 90.4% and 91.6 %. Most of the losses occur in the system belong to the filter structures. The system may be used in several applications by deciding appropriate filter structures.

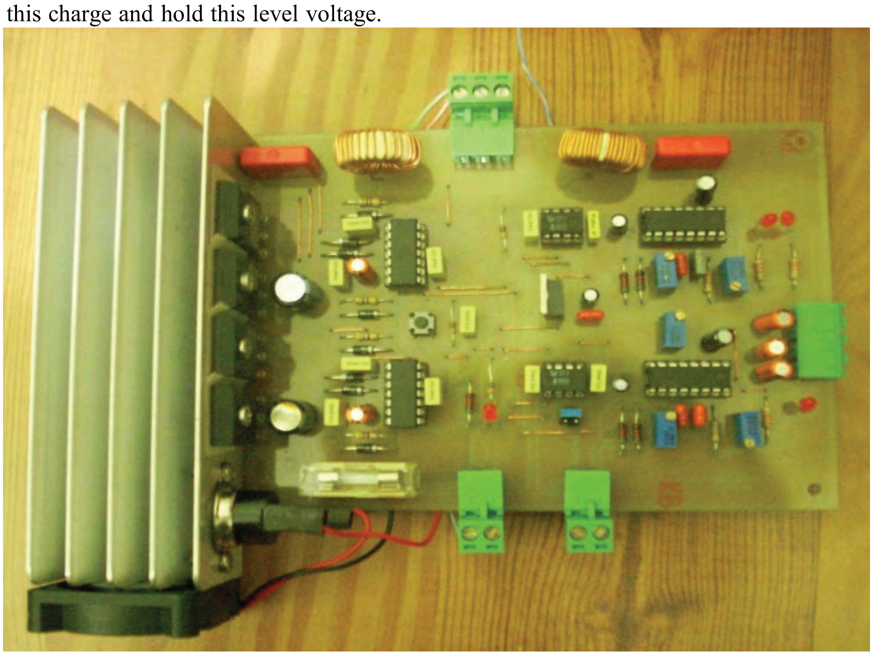

Fig. 4. Application system

Tab. 1. Efficiency of system under different voltage levels

Ölçüm No	V_{IN}	I_{IN}	P_{IN}	V_{OUT}	R	P_{OUT}	(%)
1	10.0V	0.25mA	2.5W	18.2(V_{P-P})V	18Ω	2.29W	91.6
2	21.0V	0.34 mA	7.14W	30.5(V_{P-P})V	18Ω	6.45W	90.4

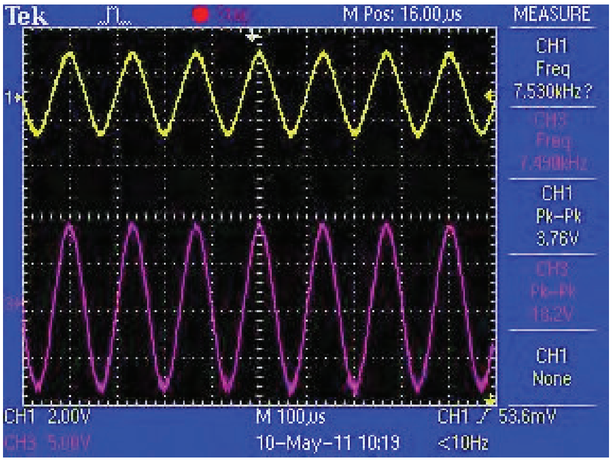

Fig. 5. Input and output waveforms of the application system

3. Conclusions

The cost of application system with high efficiency proposed in this study is very low. As the elements used in circuit can easily be supplied, fixing any problem that can be occur in operation is easy too. It can work in several frequency intervals by the help of potentiometer mounted on the system. This also helps the circuit board to be used in different areas.

Class D amplifiers are generally weak on electromagnetic interference. In system structure, if the ground and supply busses are common, the input signal is degraded because of feedback. In application electromagnetic interference is avoided by filtering the supplements and dividing the ground lines of driver part and the PWM part.

7. References

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