

Switching Mode Amplifier for High Voltage Piezo Actuator

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ABSTRACT : Piezoelectric actuator is used for various industrial products such as electric spray, dispenser, valve control etc. Since the deflection of the piezoelectric actuator depends on the applied voltage, it is required a high voltage supply for driving the piezoelectric actuators. In this study, a compact flyback type high voltage switching mode power amplifier is developed for piezoelectric actuators.

KEYWORDS –compensator, flyback converter, piezo actuator, pulse width modulation, switching mode power supply

I. INTRODUCTION

Lots of progress has been recently made on piezoelectric actuators, especially in the application of a fuel injection valve, precision displacement, and vibration control. In order to drive the piezoelectric actuator, a high-voltage power supply is required [1]. A high-voltage supply is generally bulky and a small-sized supply do not have enough voltage to drive the piezoelectric actuator. For this reasons, multiple power supplies are connected in series to supply high voltage to the piezoelectric actuator. However, it is difficult to control the output voltage and the output power of the multiple supplies and the large volume of the multiple supplies is cumbersome. In this paper, a compact high-voltage switching power supply is developed to enable a constant output voltage and output power control for the piezoelectric actuator.

II. SWITCHING MODE POWER SUPPLY FOR PIEZOELECTRIC ACTUATOR

When an external force is applied to the piezoelectric element in a specific direction, the piezoelectric element has a positive/negative charges proportional to the pressure on both sides of the plate. Because the piezoelectric element has mechanical vibration by an applied AC voltage inversely, it can be used as a spray device to atomize the materials in the liquid state by the vibration power [2]. In general, a high voltage of about 300V is necessary for smooth spray voltage. In this paper, a flyback converter is adopted for the high voltage supply because it has the advantage of low power devices suitable for development of a compact high voltage supply by simplifying the insulated structure. Switching power supply using a flyback converter is shown in Fig. 1[2].

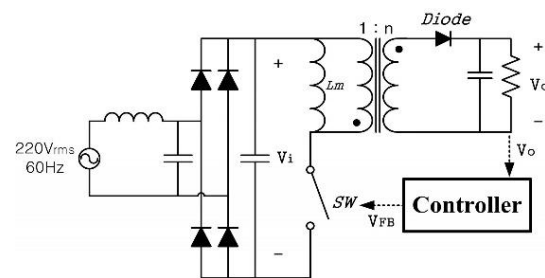


Figure 1. A flyback converter

A single-phase AC power is supplied through the diode bridge circuit in a flyback converter. When the switch is turned on, the primary coil of the transformer stores electrical energy by magnetizing inductance, L_m . When the switch is turned off, the accumulated energy is released to the secondary coil and to the output through a diode. By sensing the output voltage, the controller generates the feedback voltage, V_{FB} to control the switch on-off time.

A steady-state output voltage of the flyback converter is equal to the following relationship (1).

$$V_o = n \cdot \frac{D}{1-D} \cdot V_i \quad (1)$$

where D is duty ratio as T_{on}/T_s , T_s is switching cycles, and T_{on} is the time for turn-on switch. In (1), n represents the turns ratio of the transformer's primary and the secondary windings.

III. COMPENSATOR FOR PIEZOELECTRIC ACTUATOR SWITCHING MODE POWER SUPPLY

Fig. 2 shows the output reverse voltage compensator switching power supply of the piezoelectric actuator. The power supply control compensators are insulated by using a photocoupler. In addition, the use of adjustable regulator (KA431) type 2 controller with a compensator is designed to control the output voltage [3].

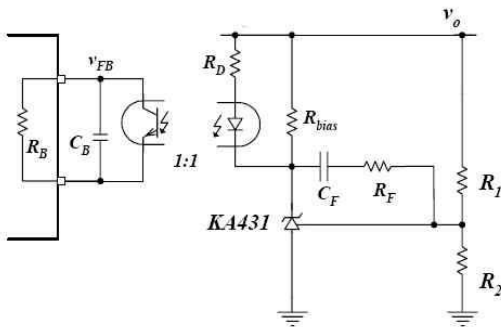


Figure 2. Power supply compensator for piezoelectric actuator

The value of each element at point zero in the design and the positional relation of the pole is equal to the expression (2)

$$\frac{V_o}{V_{FB}} = -\frac{\omega_i}{s} \cdot \frac{1 + s/\omega_{zc}}{1 + s/\omega_{pc}} \quad (2)$$

where ω_i , ω_{zc} , and ω_{pc} are determined by the circuit elements as follows:

$$\begin{aligned} \omega_i &= \frac{R_B}{R_1 R_D C_F}, \\ \omega_{zc} &= \frac{1}{(R_F + R_1) C_F}, \\ \omega_{pc} &= \frac{1}{R_B C_B} \end{aligned} \quad (3)$$

In Fig. 2, R_{bias} and R_2 are determined by the trial and error method as $R_{bias} < 10 \text{ k}\Omega$ and $R_2 \cong R_1/100$ [4].

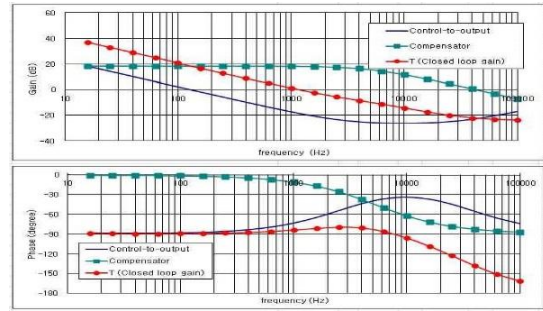


Figure 3. Bode plots of output voltage compensator

Fig. 3 shows the Bode plots of the compensator before and after applying the size of the control-to-output transfer function. The zero and the pole of the compensator transfer function are designed as around 1Hz and 5 kHz, respectively. Those values give an appropriate output voltage compensation characteristics.

IV. EXPERIMENTS

Fig. 4 shows the input and the output voltage of a switching power supply. It can be seen that the output voltage is controlled at a target value of 300V.

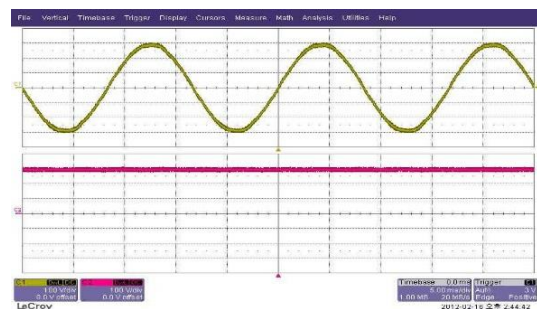


Figure 4. The output voltage waveform of the piezoelectric actuator power supply

Fig. 5 shows the current and the output voltage at 300V control switch voltage with the diode voltage.



Figure 5. Switching voltage-current, diode voltage-current

V. CONCLUSION

In this paper, a high-voltage switching power supply is developed for driving a piezoelectric actuator. The switching power supply has an insulated buck-boost type flyback converter with compact structure and has regulated constant high voltage to improve the performance of the piezoelectric vibrator for spray equipment.

VI. Acknowledgements

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