Application Note AN4148

Audible Noise Reduction Techniques for FPS Applications

1. Introduction

In general, switched mode power supplies do not generate audible noise when they operate at constant ultrasonic frequencies (>20kHz). However, some switched mode power supplies can produce audible noise at certain load conditions. Most Fairchild Power Switches are designed to enter into burst switching operation at light load conditions to reduce standby consumption, which can cause audible noise when the fundamental frequency of the burst switching bundles is in the range of human hearing as shown in Figure 1.

This application note explains the major sources of audible noise and offers useful tips to engineers to solve the audible noise problem in their Fairchild Power Switch (FPS) applications.

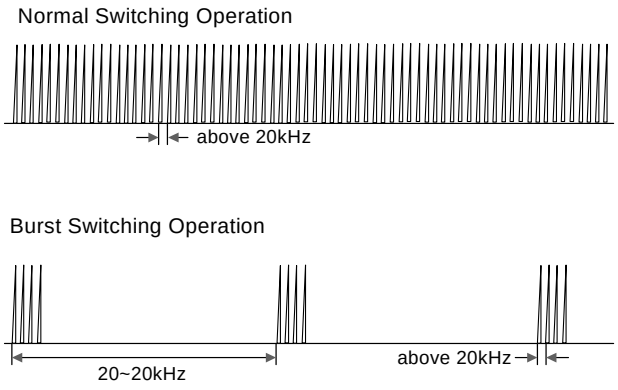

Figure 1. Burst Switching Operation

2. Sources of Audible Noise

Even though the switching frequency of the FPS is above the range of human hearing, audible noise can be generated during transient or burst operation. In most flyback converters, the major noise sources are transformers and capacitors.

-Transformer Audible Noise

Transformers can produce audible noise, since they contain many physically movable elements, such as coils, isolation tapes and bobbins. The current in the coils produces electro-magnetic fields which generate repulsive and/or attractive forces between the coils. This can produce a mechanical vibration in the coils, ferrite cores or isolation tapes.

- Capacitor Audible Noise

Ceramic capacitors can also produce audible noise, since they have piezoelectric characteristics. If there is still too much audible noise in burst operation after gluing or varnishing the transformer properly, the capacitor in the snubber network should be examined.

3. Techniques to Reduce the Audible Noise

- Varnish the Transformer

The most effective way to reduce the audible noise in the transformer is to remove the possibility of physical movement of the transformer elements by using adhesive material or by varnishing. This damps mechanical resonance of the transformer elements as well.

- Change the Transformer Design

The amplitude of mechanical vibration of the transformer is closely related to the flux swing. Therefore, the audible noise can be reduced by lowering the flux swing in the burst switching, which is given by

$$\Delta B = \frac{L_m I_{bp}}{N_p A_e} \times 10^6 \quad (T) \qquad (1)$$

where L_m is the transformer primary side inductance, I_{bp} is the current peak in burst switching, A_e is the cross-sectional area of the core in mm^2 and N_p is the number of turns of transformer primary side.

As can be observed in equation (1), the flux swing can be reduced by increasing N_p and/or A_e while keeping L_m constant, which results in reduced audible noise.

- Reduce the Current Peak in Burst Switching

Equation (1) also shows that the flux swing can be decreased by reducing the current peak (I_{bp}) in burst switching. By using slope compensation, the current peak in burst switching can be reduced. Unfortunately, this technique can be applied only to the FPSs below, whose burst switching levels are determined by the feedback voltage level.

- FSDM0465R, FSDM0565R, FSDM07652R, FSDM1265R
- FSCM0565R, FSCM0765R, FSD200, FSD210

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The slope compensation circuit can be easily implemented with one capacitor and one resistor as shown in Figure 2. This slope compensation circuit introduces voltage dip in the feedback voltage reducing the current peak in burst switching as shown in Figures 3 and 4 with FSDM0565R as an example. In the case of FSDM0565R, switching stops when the feedback voltage drop below 0.5V and switching resumes when the feedback voltage reaches 0.7V. Thus, the burst switching current is determined by the feedback voltage and can be reduced by introducing dip on the feedback voltage.

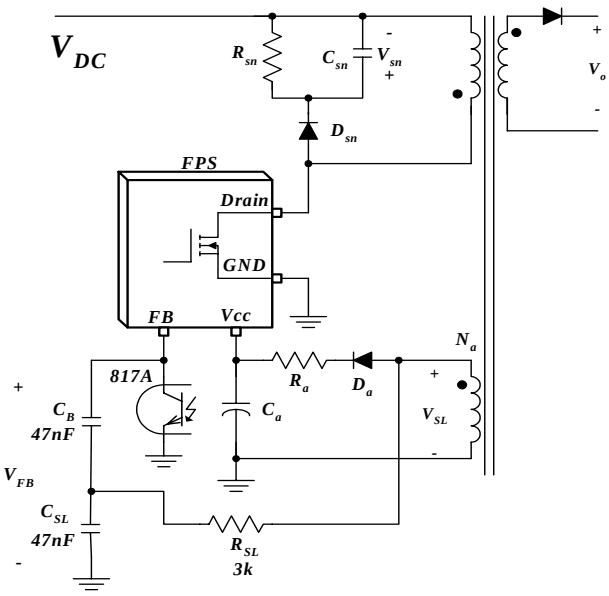

Figure 2. Slope Compensation Circuit

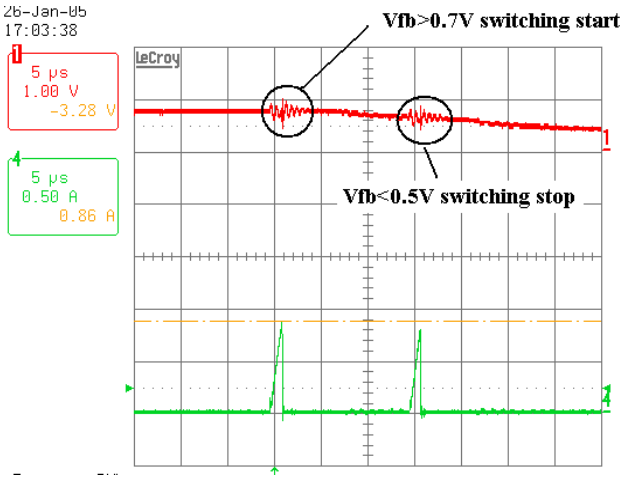

Figure 3. Burst Switching Waveforms without Slope Compensation (FSDM0565R)

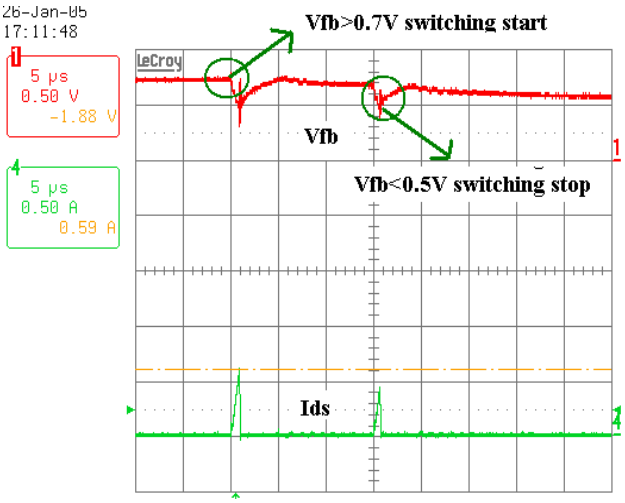

Figure 4. Burst Switching Waveforms with Slope Compensation (FSDM0565R)

- Change the RCD snubber network

As mentioned in the previous session, ceramic capacitors can also produce audible noise, because of their piezoelectric characteristics. By replacing the ceramic capacitor with a film capacitor as shown in Figure 5, the audible noise can be reduced.

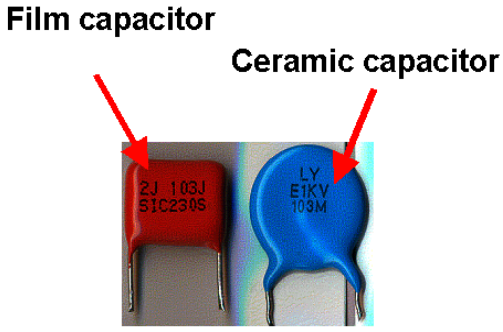

Figure 5. Film Capacitor and Ceramic Capacitor

Another way to lower audible noise is to reduce the snubber capacitor value, which decreases the pulse current that charges the capacitor every time the FPS resumes switching operation in burst mode as shown in Figure 6. A zener clamp circuit using a TVS (Transient Voltage Suppressor) as shown in Figure 7 can reduce the audible noise caused by the snubber capacitor as well.

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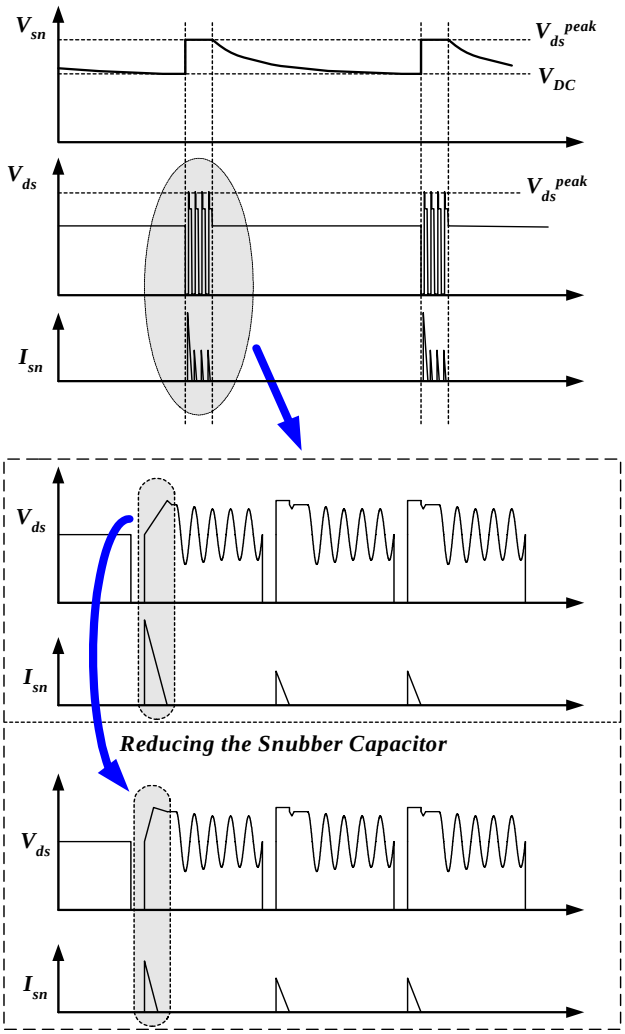

Figure 6. Effect of Reducing the Snubber Capacitor

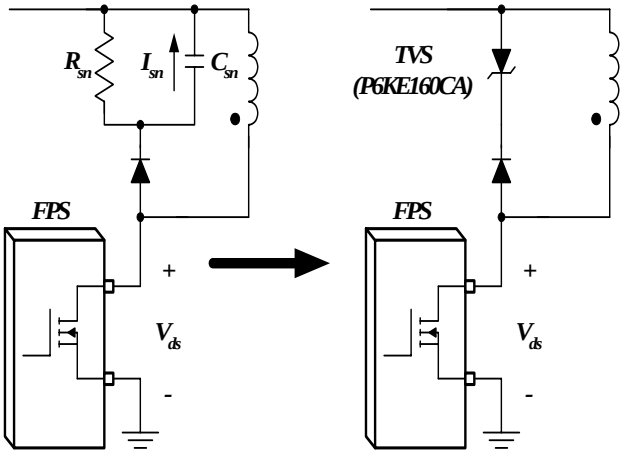

Figure 7. Zener Clamp Circuit with TVS

- Change the Fundamental Frequency of Burst Switching

In general, human ears are most sensitive to frequencies of 2~4kHz and are less sensitive to frequencies which are higher or lower as shown in the equal loudness curves of Figure 8. These are graphical representations of the sensitivity of the ear to frequencies over the range of human hearing at various loudness levels. Each line shows the intensity level for the range of frequency that gives a subjective perception of similar loudness in reference to a starting level at 1kHz.

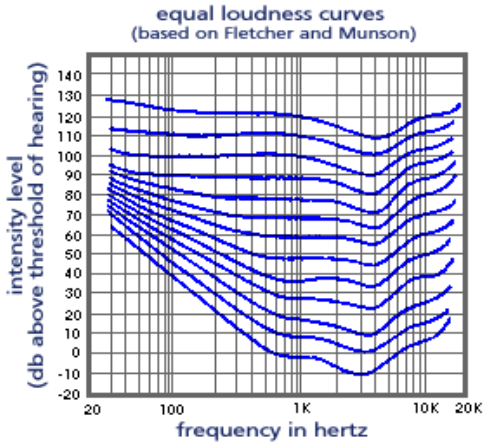

Figure 8. Equal Loudness Curves

Therefore, the subjective feeling of loudness can be lowered by moving the fundamental frequency of noise out of the 2~4kHz range. The fundamental frequency of burst switching can be changed by modifying the feedback network. Figure 9 shows a typical feedback network. The fundamental frequency can be reduced by one or more of the following methods

- increasing C_F
- increasing R_D
- increasing C_B
- decreasing R_F

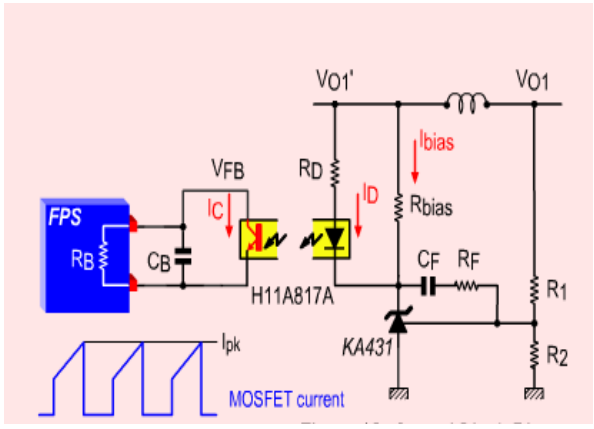

Figure 9. Typical Feedback Network of FPS

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Figure 10 shows burst switching waveforms with feedback network parameters as

- R_F=1.2k, C_F=100nF, R_D=100, C_B=22nF

In this case, the fundamental frequency of burst switching is 1.2kHz. When R_D is increased from 100Ω to 1kΩ, the fundamental frequency is reduced to 142Hz as shown in Figure 11. With this circuit modification, the fundamental frequency is lowered along with the subjective perception of loudness. However, use caution when lowering the fundamental frequency since the number of switchings in each burst switching bundle as well as the output voltage ripple increases when the fundamental frequency decreases.

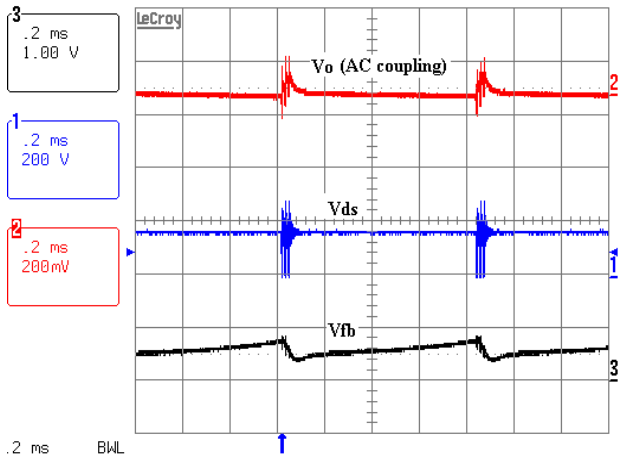

Figure 10. Burst Switching Waveforms (Fundamental Frequency is 1.2kHz)

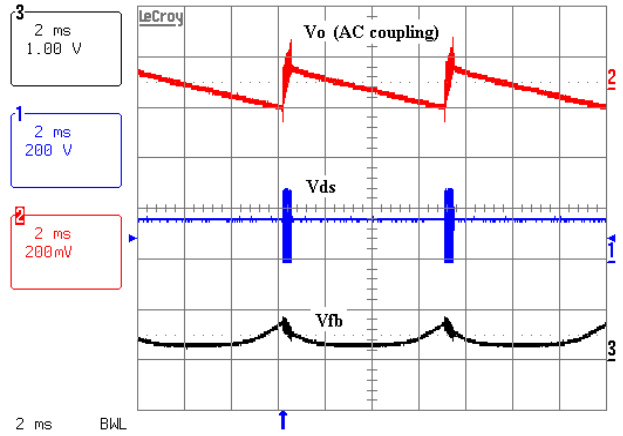

Figure 11. Burst Switching Waveforms (Fundamental Frequency is 142Hz)

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