Application Note AN-24
Guidelines to Reduce Audible Noise in Switching Converters

Design Guide

Introduction

Electronic and magnetic components can generate audible signals when they are excited at frequencies in the range of human hearing. This phenomenon has been observed since the early days of switched mode power conversion. It is well known that switched mode power converters operating at constant ultrasonic frequencies can produce audible noise if their loads are modulated with audio frequency components.

Audio frequency signals are not usually a concern with converters that operate at low power levels. There may be applications, however, when designers will need to reduce the acoustic emissions from their circuits.

Human perception of sound is very subjective. It is difficult to assert how much will be audible, and even more difficult to determine how much will be perceived as sound in a given application. Power Integrations has studied the acoustic emissions from switched mode power conversion circuits with sophisticated audio engineering equipment. The instruments can measure absolute sound pressure levels and spectral content with great accuracy.

Acoustic emissions are similar to electromagnetic emissions, but there are no universal standards to provide a benchmark for acoustic compatibility. Therefore, designers may wish to follow these guidelines to reduce the acoustic emissions from their products if they have any concern about audible noise.

Transformer Noise

In most flyback converter applications, the transformer is the major source of audible noise. Designers should not be alarmed if they hear noise from the first prototype transformer on their breadboard. Use of appropriate construction techniques that are well known to manufacturers will reduce the noise substantially at virtually no additional cost. Care in assembly of the prototype transformer can duplicate the performance of the production device. Transformer noise can originate from several mechanisms. Each one produces a mechanical displacement that launches sound waves into the surrounding air. These include, but are not limited to:

- Relative Motion - The attractive force between two core pieces can cause them to move, compressing the material that keeps them apart.
- Percussion - If the faces of the core pieces can touch, they can hit or scrape together when they move in response to flux excitation.
- Bending - A gap in only the center leg of an EE or an EI structure can allow the core pieces to bend or flex from the attractive force between them.
- Magnetostriction - The core material changes dimension in response to the flux density. For common power ferrites the change is less than 1 ppm.
- Bobbin Motion - Displacement of the core pieces may be transmitted and amplified through the bobbin.
- Coil Motion - Current in the coil produces attractive and repulsive forces that tend to move the wires.

These sources of motion act together to form a complex mechanical system that can have a strong resonance at one or more frequencies in the range of human hearing. The structures used most often in offline flyback converters below 10 watts tend to resonate between 10 kHz and 20 kHz. The motion can become audible when the fundamental frequency of the flux excitation or any of its harmonics passes through a region of mechanical resonance. Designers should vary the load over its entire range to check for audible noise, particularly if there is a dynamic load requirement.

The degree to which any of these mechanisms contributes to audible noise depends on the design. Fortunately, engineers may apply simple construction techniques that are very effective at reducing audible noise from multiple mechanisms.

Construction Recommendations

The most effective way to reduce noise from the transformer is to use an appropriate adhesive in assembly. The adhesive material should occupy the space between all mating surfaces of the two core pieces. In EE core structures with a center leg gap it is important that the center gap be completely filled with adhesive, and that the material forms a strong bond over the entire surface on opposing faces of each leg. One of the core pieces should be glued to the bobbin.

Transformer manufacturers will often be in the best position to select an appropriate material because they usually have their own list of preferred adhesives that work well with their individual processes. The material for this purpose should be a rigid type. The desired characteristics are most often found in hard epoxies and thick cyanoacrylates. Soft compounds like silicone RTV are not effective.

Gluing Procedures: The procedure for application and curing of the adhesive is very important. This is especially true in the fabrication of prototype transformers for the prototype, where the process is neither automated nor refined.

Although transformer suppliers may be familiar with the use of a particular material in their manufacturing process, it is essential that they understand the purpose of the procedure, and that they consistently use enough glue. Incomplete gluing may be adequate to hold the pieces together, but it will not give the expected reduction in noise. Consistency in the gluing process is necessary to produce a high yield of quiet transformers.

Be sure the surfaces are clean. Use plenty of adhesive. One method that works well for an EE core is to dip the ends of all three legs of each piece into the adhesive so that it thoroughly wets each face. Surface tension will hold the proper amount of adhesive during assembly. Adhesive from the gap in the center leg will glue the core to the bobbin.

A proper adhesive will not wick away or leak out while it cures. Clamp the two core pieces together during the cure to promote good adhesion. Epoxies or other adhesives that require baking to cure are more likely to produce a reliable full cure in the center leg.

The addition of an adhesive between mating surfaces may reduce the inductance of the transformer due to expansion of the glue while curing, particularly if the original gap is small. Designers should confirm that the inductance is within the desired limits after gluing. It may be necessary to start with a smaller gap in the center leg to compensate for the thickness of the glue in the outer legs.

If a prototype transformer is still noisy after gluing, cut away the bobbin to inspect the gap in the center leg. In most cases of noisy transformers, the gap will not be filled completely. If the center gap is filled without voids, separate the core pieces to expose the mating surfaces of the outer legs. Check for a good bond over the entire surface.

Adhesives known to be used by transformer manufacturers that are effective to reduce audible noise are:

- Product No. 2095, a black epoxy from EPOLAB Chemical Industries, Inc., Taiwan
- Product No. 638, an anaerobic adhesive from Loctite Corp. (for outer legs only)

Adhesives that are good for laboratory use are:

- Two part liquid household epoxy
- High viscosity household cyanoacrylate (super glue gel)

Other Construction Considerations

Varnish is often used in the manufacture of transformers to improve reliability. It keeps out moisture and adds durability to fine wires. While varnish can be beneficial to reduce audible noise, designers should use caution with varnish impregnation.

Although it is unrelated to audio noise, the users should be aware that varnish with a high dielectric constant can raise the capacitance of the primary winding. Increased primary capacitance will lower the self resonant frequency of the transformer, increase the peak current of the power switch at turn-on, and reduce the efficiency of the power supply.

Applications that require fully encapsulated or potted magnetic components usually require no additional procedures to reduce audible noise. If desired, potting could be used just for noise reduction.

Transformer Design Recommendations

Lower peak flux density produces less noise. If further reduction in audible noise is desired for a given transformer construction, the designer can reduce the peak flux density. For a transformer with no adhesive between the core pieces, a reduction in peak flux density from 3000 gauss to 2000 gauss can lower the audible emissions by 10 to 15 dB. The reduction will be about 5 dB for the same transformer that is properly glued. It is generally accepted that humans perceive a 10 dB change in sound pressure level as a factor of 2 in loudness.

Note that a design for lower peak flux density will require more turns and a larger gap to achieve the same output power with a given core. More turns will lead to more leakage inductance, which may require changes in circuit component values to stay within device limits and to meet product specifications.

The magnitude of audible noise depends on the flux duration as well as the peak flux density. For a given peak flux density, less time to go from zero to the peak and back to zero produces less noise. Transformers designed to operate at higher frequencies will tend to produce less noise when they are excited by audio frequency signals in the power converter.

Capacitor Noise

While the flyback transformer is usually the major contributor to audible noise, the ceramic capacitors can also be sources of substantial acoustic emissions. If there is still too much audible noise with a properly glued transformer, the designer should examine the capacitors in the clamp and snubber circuits that see large voltage excursions.

All dielectric materials deform under the stress of an electric field. This electrostriction effect is proportional to the square of the electric field intensity. Some dielectrics exhibit an additional piezoelectric effect, which is a linear displacement proportional to the electric field intensity. The piezoelectric effect is usually the dominant mechanism that produces noise from the capacitors.

The nonlinear dielectric material in small, low cost ceramic capacitors typically contains a high percentage of barium titanate, which is piezoelectric at normal operating temperatures. As such, these components tend to make more noise than capacitors with linear dielectric compositions.

To determine if the ceramic capacitor is a major source of noise, replace it with one having a different dielectric. Capacitor manufacturers by convention use the letter K to represent the dielectric constant. High-K dielectrics such as Z5U and Y 5V are prone to high audible noise because of the piezoelectric nature of their dielectric material. Mid-K dielectrics like X7R and BX will make less noise, while low-K linear dielectrics like NPO or COG will make the least noise. These linear dielectrics are usually based on titanium dioxide, which is not piezoelectric.

Another option is to replace the ceramic capacitor with a plastic film capacitor. Take care to be sure the replacement can withstand the repetitive peak current and voltage stress.

Packaging Considerations

Designers should consider the packaging of their product when making decisions related to audible noise. Any enclosure can make a dramatic reduction in the transmission of audible noise from the PCB. An ordinary unventilated plastic case can attenuate the sound by about 20 dB. The engineer should evaluate the effect of the enclosure on the thermal characteristics of all components in the circuit.

Perspective on Audible Noise

Acoustic emissions from switched mode power converters are analogous to electromagnetic emissions. In each case, designers need to overcome a small inconvenience to benefit from a superior technology. Unlike electromagnetic emissions, however, there are no universal standards for low levels of acoustic emissions to tell the designer what is acceptable in his application.

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A	Introduction release.	07/25

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