Technical Article

Make a Boost Converter Quieter

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In order to minimize the power loss of a boost converter under light or no load conditions, designers usually use the Pulse Frequency Modulation (PFM) to lower the switching frequency and hence the associated switching losses. In PFM more and more switching pulses are skipped as the load is getting lower, as shown in Figure 1. Obviously these scattered switching pulse trains carry the subharmonic frequency that varies with load. Depending on the time duration of the dead band between the switching pulse trains, the subharmonics may appear as the Radio Frequency (RF) noise, or audible noise. The RF noise can cause unwanted interferences with the performance of the entire system, and the audible noise is not only unpleasant but also risks compromising the mechanical integrity of the system. Therefore, these noise issues should be resolved.

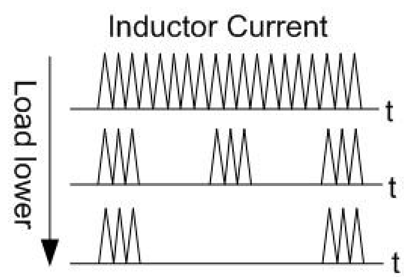


Figure 1. Inductor Current at Various Loads

1. Method to Prevent the Audible Noise Issue

In a DC/DC converter including the boost, the audible noise can be produced by both the power inductors and multi-layer capacitors. However, the power inductors in the Personal Electronics (PE) applications are mostly molded, therefore they are not a big concern. The multi-layer ceramic capacitors are the main source of audible noises.

The multi-layer ceramic capacitors offer a nice combination of low equivalent series resistance (ESR), low equivalent series inductance (ESL) and small size. However, they suffer from the piezoelectric effect, namely the voltage applied to their terminals induces mechanical stress. Figure 2 shows a ceramic capacitor soldered on the PCB. Its dielectric is stretched or compressed when the applied voltage varies. If the applied voltage carries a component of subharmonics that falls in the 20 Hz to 20 kHz audible frequency range, it will produce the audible noise, and the resulted sound pressure level versus frequency is shown in Figure 3.

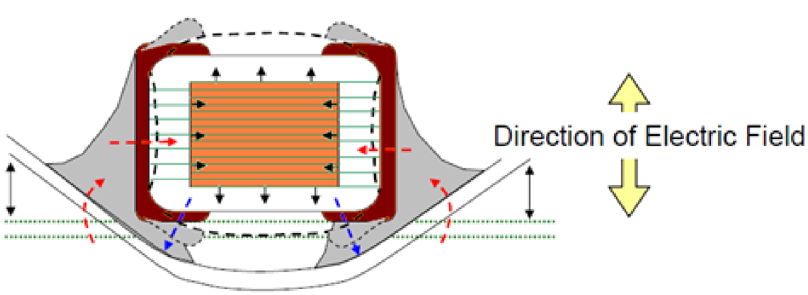
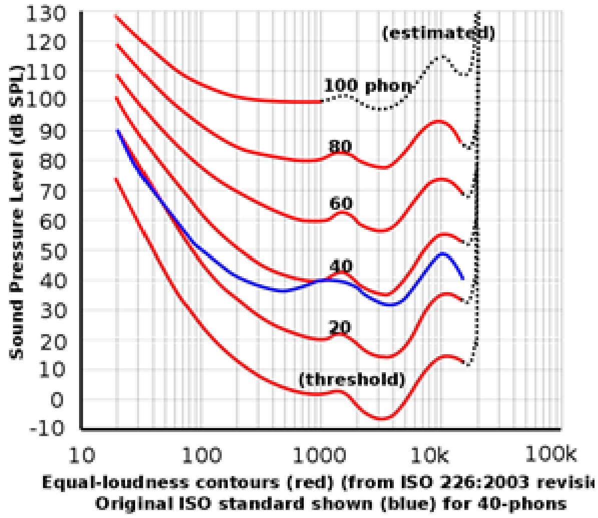


Figure 2. Mechanical Stress on the Ceramic Capacitor



Equal-loudness contours (red) from ISO226:2003 revision, original ISO standard shown (blue) for 40-phons

Figure 3. Sound Pressure Level vs. Frequency

To minimize the audible noise, both mechanical and electrical methods can be employed. The mechanical method is basically the PCB layout optimization but it can be a very difficult and complex task, and it can easily increase the manufacturing costs. The preferred method, which is electrical, can resolve the issue by means of controlling the circuit operation. One effective method is to employ a non-audible PFM scheme at light or no load condition. A good example is the TPS61253A boost converter, which includes a unique control technique to keep the PFM frequency above the audible band.

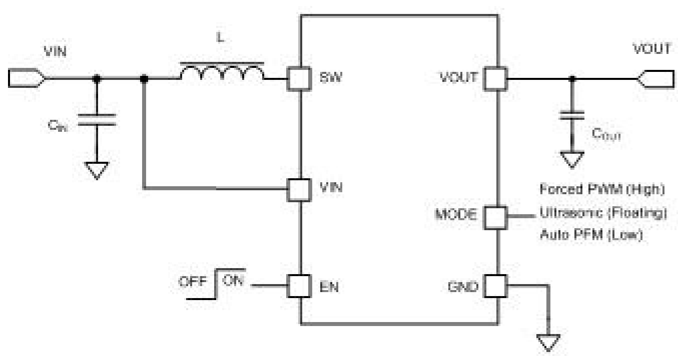


Figure 4. TPS61253A Typical Application Circuit

As shown in Figure 4, the TPS61253A can be configured by the MODE pin for different operation modes. There are three modes to choose from. When the MODE pin is pulled low, it operates in auto PFM mode. When it is pulled high, it is in the forced PWM mode. When it is left open or floating, it is set to the ultrasonic mode. These three modes can be selected dynamically during operation by externally reassigning the MODE pin condition.

When the TPS61253A is configured in the ultrasonic mode, it automatically enters the PFM mode as soon as the valley current of the power inductor crosses zero. As the load decreases further, the valley current limit will go negative to reduce the number of skipped switching pulses, and this effectively prevents the subharmonic frequency from falling into the audible band. Bench tests prove that the subharmonic frequency in the ultrasonic mode is typically 53 kHz at no load condition, i.e. it will always stay above the audible band over the entire load range.

Figure 5 below shows the mode transition from PWM to PFM and then to ultrasonic mode with the load getting lighter and lighter.

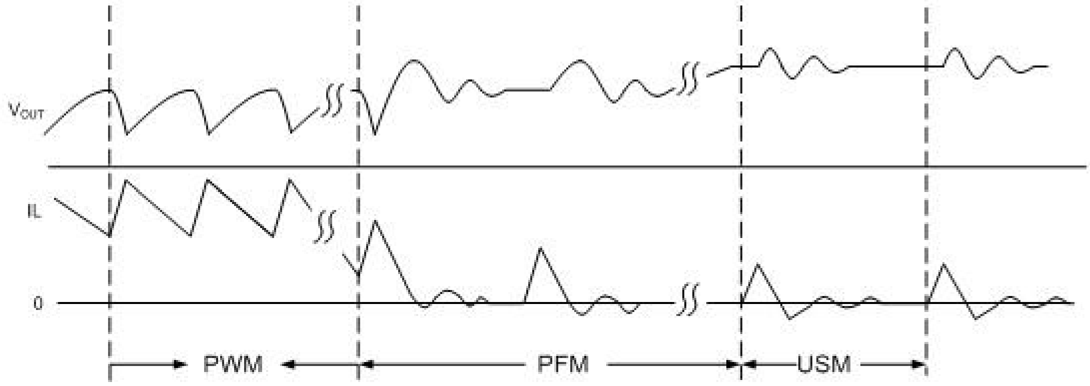


Figure 5. TPS61253A Operation Mode with Various Loads

Test Condition: VIN = 3.6 V, VOUT = 5 V, Load = 0 A, L = 0.56 µH, XEL3515-561MEB, COUT = 7 µF, Ultrasonic Mode

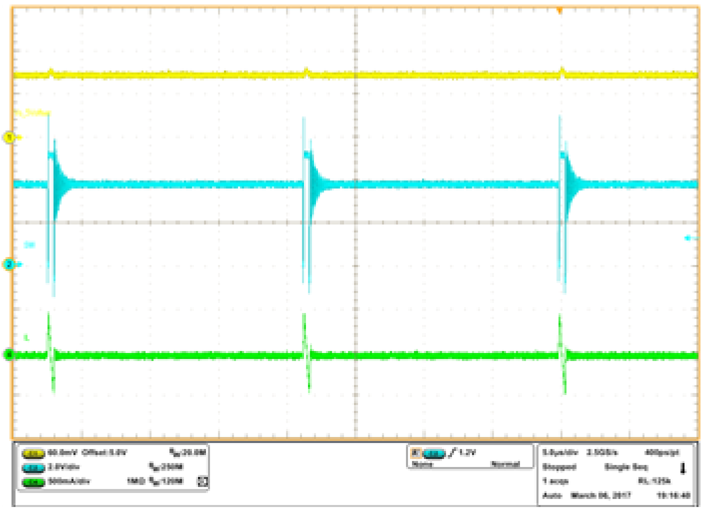


Figure 6. Steady State Waveforms of USM at No Load

2. Method to Cope with the RF Noise Issue

The second noise is the RF related noise, which is more critical in applications like Near Field Communication (NFC). There are two sidebands for the subcarrier load modulation, the upper sideband is at 14.4 MHz and the lower one at 12.7 MHz.

The sub-carrier frequency fs is 1/16th of the carrier frequency fc, namely fs = fc / 16. It means that the sub-carrier frequency is in a range from 794.5 kHz to 900.5 kHz.

To avoid the potential noise interference with the NFC, the power converter should not generate noise in the sub-carrier frequency band. Otherwise, the application work-around solution like the PCB layout optimization or shielding must be implemented, and it undoubtedly raises the over cost.

Figure 7 shows the modulation scheme with subcarrier, with the subcarrier frequency varying from 12.7 MHz to 14.4 MHz.

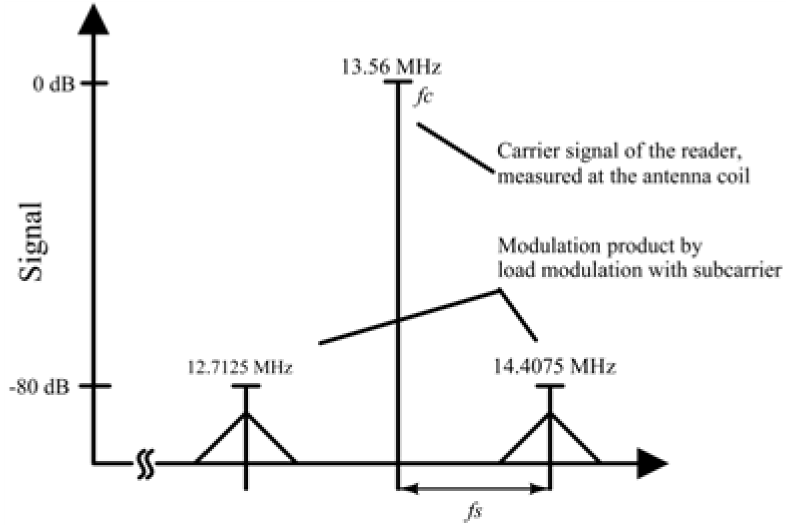


Figure 7. NFC Modulation Products Using Load Modulation with a Subcarrier

The proposed solution is to maintain the switching frequency of the boost converter above the subcarrier frequency band. This can be easily achieved with the TPS61253A. Its switching frequency can be conveniently set at 3.8MHz typical, always higher than the subcarrier frequency band, by configuring the MODE pin to the forced PWM mode.

Because the TPS61253A supports dynamic MODE programming during operation, it offers a valuable flexibility and programmability for a boost converter for different application environment. Figure 7 shows the efficiency of a typical design in different operation modes, including the Ultrasonic or Force PWM for low noise purpose, and the Auto PFM Mode for enhanced light load efficiency.

TPS61253A efficiency measurement is conducted at the conditions of:

VOUT = 5 V, Load = 100 µA – 200 mA, L = 0.56 µH, XEL3515-561MEB, COUT = 7 µF (effective@5V)

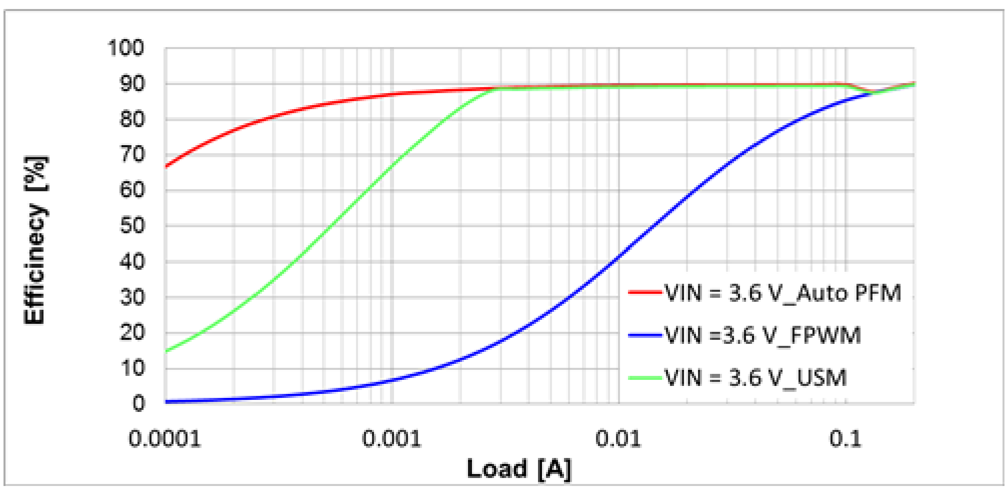


Figure 8. TPS61253A Efficiency at Auto PFM / Forced PWM / USM

Conclusion

Audible noise or the RF noise generated by the boost converter can severely affect system performance. The conventional solutions by the mechanical means are normally complex and costly. To resolve the issue at the root cause, this blog discusses more elegant approaches, which are new PFM control schemes that can prevent the audible and RF noise completely. The TPS61253A is an easy to use solution for a variety of applications that features ultrasonic PFM mode, auto PFM mode, and forced PWM mode in one device. Its ultrasound mode eliminates the audible noise, the forced PWM mode prevents RF noise from affecting the NFC operation, and the auto PFM mode delivers the best efficiency at light load. Test results with the TPS61253A verify the concepts discussed in this blog. As well, the PFM schemes discussed in this blog can be applied to other DC/DC converter topologies, improving the overall system performance without additional cost. Start a power supply design in WEBENCH® Designer with the TPS61253A now.