Frequency Selection in Switching Power Supply Designs (Part II)

Introduction

This article is the second part of a two-part series delving into switching frequency design. Part I reviewed how to calculate the key indicators for switching frequency, as well as the challenges of higher frequencies. Part II will apply these switching frequency concepts to practical scenarios.

Power engineers must consider numerous factors to determine the operating frequency range and variation characteristics of practical applications. This article will explore the basic points to design a general power supply across a frequency axis that has been sorted from low to high frequencies.

Frequencies between 20Hz and 20kHz

Humans are able to hear frequencies between 20Hz and 20kHz. To improve light-load efficiency, switching power supplies often reduce frequencies to be within this audible range. In particular, frequencies at about 5kHz create sharp and shrill sounds. The main source of this sound is from the capacitive and inductive energy storage devices in the circuit (see Figure 1).

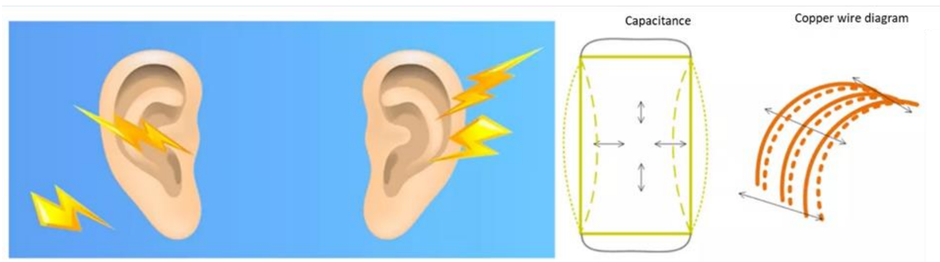

Figure 1: The Audible Range

Under light-load conditions, the power supply's switching frequency falls within the audible range. Owing to the capacitor's piezoelectric effect and the inductance coil's repulsive force, the pulse energy created during switching causes the devices to physically vibrate. Designers should consider how to minimize environmental sound pollution that is generated by the low-frequency switching noise.

Reducing Audible Noise

To mitigate sound created when the frequency is between 20Hz and 20kHz, follow the steps below:

1. Keep the switching frequency above 20kHz, or limit the energy of the noise source within the <20kHz frequency band. For example, light loads (or no-load conditions) limit the current peak of both inductors and capacitors.
2. Fix the physical vibration between parts, such as inductors and capacitors (e.g. transformer dipping, using ceramic capacitors with bases).

Figure 2 shows the peak current at a fixed frequency of 25kHz.

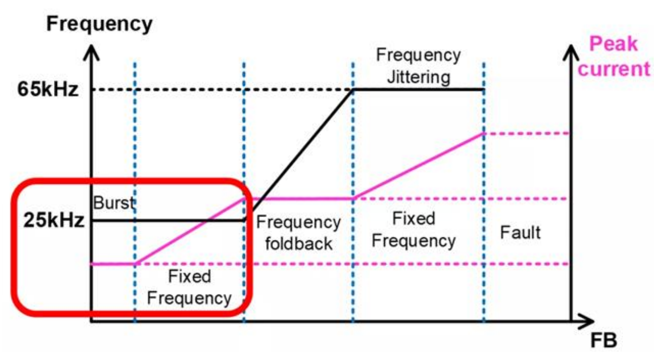

Figure 2: Peak Current (25kHz Fixed Frequency)

Frequencies between 20kHz to 150kHz

The broad variety of power supply types — including large, universal, small, and medium-power switching power supplies — can be divided into two categories: high-voltage, isolated power supplies and low-voltage, non-isolated power supplies.

High-voltage isolated power supplies are commonly used in adapters and lighting solutions. They are generally designed to operate between 20kHz and 150kHz due to silicon's characteristics, as well as EMI standards.

Silicon's Characteristics

Silicon (Si) is a common component in mainstream MOSFETs that determines the frequency range based on electron mobility, the degree of bandwidth, body diodes, and parasitic devices (i.e. parasitic capacitance). These variables impact the device's application.

With advances in materials science, semiconductor switching devices using new materials (e.g. silicon carbide (SiC) and gallium nitride (GaN)) are gradually entering the mass production stage to make smaller products. These devices have a bandgap limit and a mobility rate that is 2 to 4 times greater than that of silicon, with parasitic capacitance and impedance up to 10% to 30% of silicon. Altogether, these characteristics address the switching loss caused by high frequency.

Figure 3 shows Si characteristics across different power, voltage, and frequency ranges.

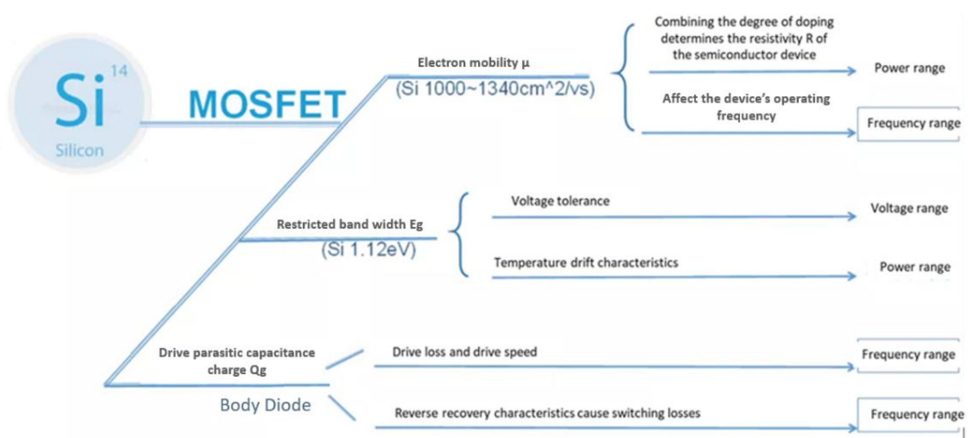

Figure 3: Si Characteristics

EMI Standards

According to the EMI standard, the switching frequency is set below 75kHz. The peak doubling noise falls within the <150kHz range (see Figure 4). Since the <150kHz frequency band has looser restriction standards, there are larger general inductor and power capacity values as a result.

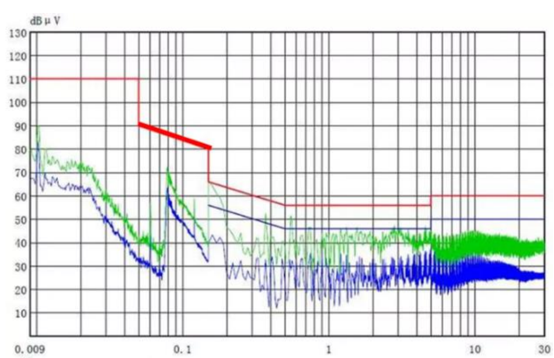

Figure 4: Peak Doubling Noise at a <75kHz Switching Frequency

Power Line Carriers

In electric meter power supply designs, there are some switching frequency points to avoid, such as the frequency point of the power line carrier's (PLCs) signal transmission. PLCs use the existing AC power supply line to transmit the communication signal.

Signal transmission is a fixed, characteristic communication frequency (e.g. 58kHz, 77kHz, and 115kHz). To obtain information, the PLC interprets the fixed high-frequency signal that is superimposed on the power frequency. However, if the communication signal is affected by the power switch signal, a communication error results and affects PLC operation (see Figure 5). A power scheme can be adopted to set a fixed switching frequency that prevents communication interference.

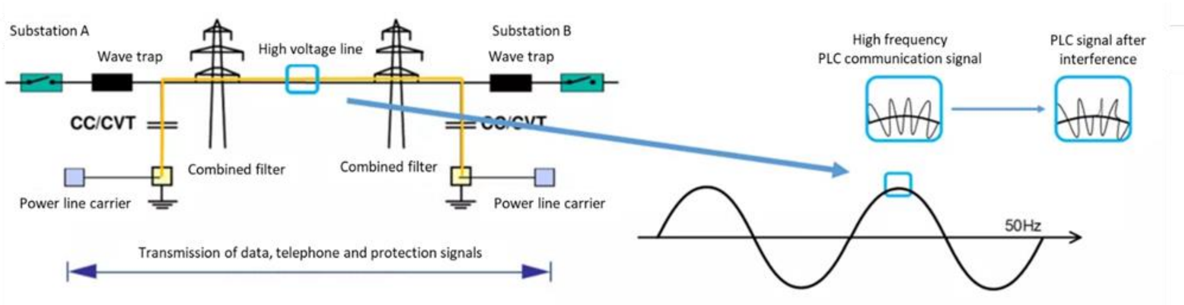

Figure 5: Interference of High-Frequency PLC Communication Frequency

Frequencies between 200kHz and 1MHz (Or Higher)

Medium- and low-voltage non-isolated switch designs use higher frequencies. These designs are widely distributed in commonplace electronic products.

Medium- and low-voltage non-isolated switch designs must integrate efficiency, heat generation, and small volume into one solution. These applications are usually between 200kHz and 1MHz or higher, which is also the main frequency band for on-board switching power supply operation. CISPR 25 sets strict standards for the EMI of automotive-grade devices, with clear limits on switching power frequencies <350kHz, or between 525kHz and1610kHz (see Figure 6). It is reasonable to set switching power frequency ranges between 400kHz and 500kHz, or to have them exceed 1.6MHz.

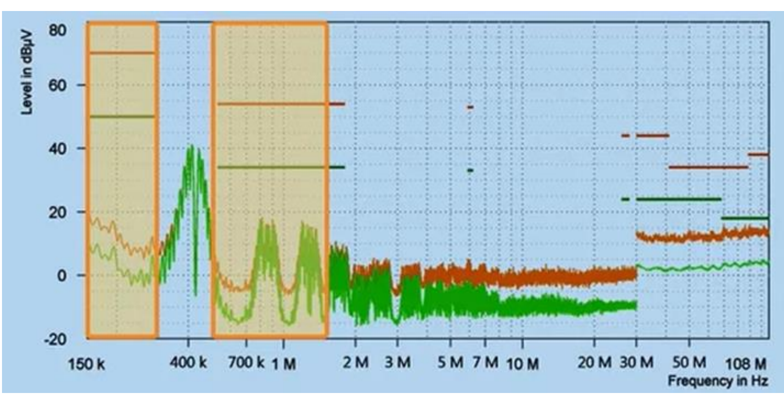

Figure 6: CISPR 25 Switching Power Frequency Limits

In addition to the EMI requirements, automotive power supplies must avoid the AM and FM frequency bands. Because the low-frequency AM band is the switching power supply's main working frequency band, the actual frequency band remaining for the switching power supply is limited.

High-Frequency Switching Power Supply Design

High frequency is an important feature for future switching power supplies. Previously, it was understood that increasing frequency reduces energy storage. Combined with the improvements made toward silicon technology, the entire switching power supply circuit can now be integrated into a very small space, called a module power supply. In this scenario, the current mainstream frequency is increased between 3MHz and 4MHz. The module's power supply can operate within this range, and the chips can be as small as 2mmx3mm (see Figure 7).

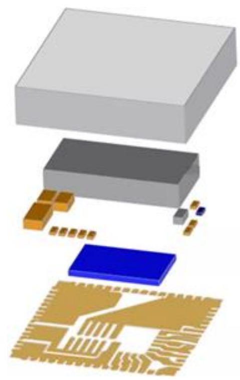

Figure 7: The Module Power Supply on a 2mmx3mm Chip

High-frequency designs reduce the power supply requirements of inductive devices, and eliminate the skeleton and copper wire from traditional transformers (see Figure 8). They also use the PCB's multi-layer coils to achieve a thin plane transformer design. In the high-frequency areas, only the PCB coils or PCB parasitic inductors are used to complete the power transmission. High-frequency designs can eliminate the need for a magnetic core and hollow inductor, which can significantly reduce the cost of the device. In conclusion, high-frequency designs minimize the size of isolated power modules.

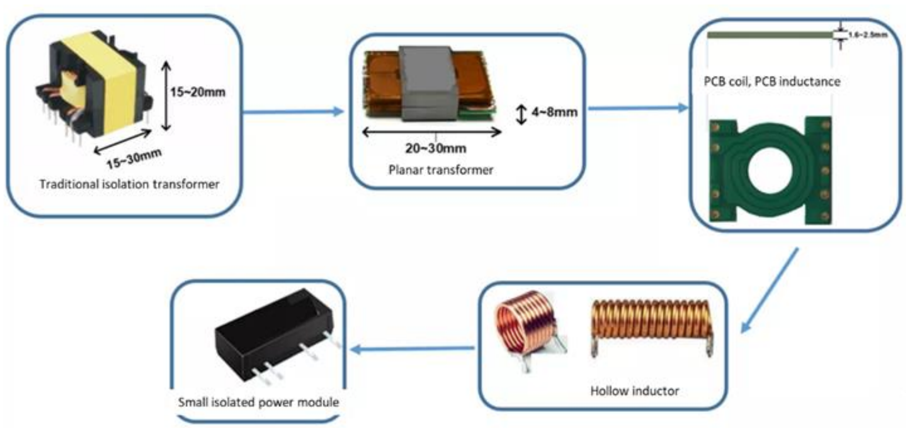

Figure 8: Traditional Transformer Components

Conclusion

In this article, we continued to explore how to design switching power supply designs with three different frequency ranges. With the popularity of new power supply devices, power designers are seeking approaches to further improve functionality and simplify design. MPS offers innovative power solutions that enable switching power supply designs for fixed, variable, and high-frequency power supply applications.