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Hard Switching vs Soft Switching: A Case Study

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Xantrex was the first to offer programmable DC power supplies that use "soft switching" technology. Xantrex programmable DC power supplies use this superior switch-mode topology, reducing high frequency noise while improving both efficiency and reliability

"Hard Switching" vs. "Soft Switching"

Meeting international safety and regulatory standards can be difficult, especially for modern high frequency power converters with embedded high-speed digital controllers. The high speed switching that occurs in these designs leads to more electromagnetic energy being radiated at levels that can easily exceed the maximum allowable limits. Xantrex utilizes "soft switching" in the design of each of its programmable DC power supplies to successfully meet international standards.

Good radio frequency (RF) design techniques will help contain these emissions, but often the energy needs to be controlled at its source. A relatively new technique called "soft switching", or "zero voltage switching", uses circuit resonance to ensure that power-transistors switch at or near a zero voltage level. This reduces the stress on the part, and also greatly reduces the high frequency energy that would otherwise be radiated as RF noise.

"Hard Switching"

Traditional high frequency switch-mode supplies, which rely on generating an AC waveform in the range of 100 kHz to 200 kHz to drive the main power transformer, have used power transistors to "hard-switch" the unregulated input voltage at this rate. This means that a transistor turning on will have the whole raw input voltage, typically in the range of 350 V, across it as it changes state. During the actual switching interval (less than 0.5 microsecond) there is a finite period as the transistor begins to conduct where the voltage begins to fall at the same time as current begins to flow. This simultaneous presence of voltage across the transistor and current through it means that, during this period, power is being dissipated within the device. A similar event occurs as the transistor turns off, with the full current flowing through it. (See Figure 1.)

Designers that use a hard-switching topology are in a no-win situation when they try to reduce wasted power, and still meet the European EMC directive. As the switching period is reduced through the use of improved driving circuitry, the faster rise and fall times generate more high frequency energy that is radiated and conducted out of the unit as unacceptable radio frequency interference (RFI). If the rise and fall times are intentionally slowed to reduce the radio frequency interference, the power losses in the transistor increase proportionally, increasing the thermal stress on the part, thus reducing its lifespan. In this way, older hard switching topologies are a compromise between electrical efficiency reduction and EMC “noise” trade-offs.

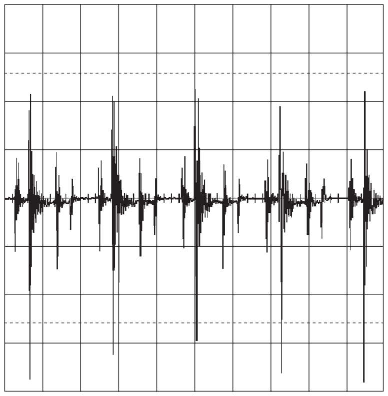

Figure1. “Hard Switching” topology power loss waveform for a bridge MOSFET (320 W/div) showing high instantaneous peak power loss during each switching cycle.

“Soft Switching”

More recently, new power conversion topologies have been developed which dramatically reduce the power dissipated by the main power transistors during the switching interval, while at the same time nearly eliminating much of the generated radio frequency energy, or high frequency “noise”. The most common technique employed has been a constant frequency resonant switching scheme, which ensures that the actual energy being dissipated by the active device is reduced to nearly zero. This method, commonly called “Zero Voltage Switching” (ZVS) or “Soft Switching” uses the parasitic output capacitance of the power transistors (typically MOSFETs) and the parasitic leakage inductance of the power transformer as a resonant circuit. Using this resonant circuit, the output inductance, the parasitic drain-source body diodes of the MOSFETs, and an appropriate switching sequence allows the voltage across each transistor to swing to zero before the device turns on and current flows. Likewise, at turn-off, the voltage differential across the transistor swings to zero before it is driven to a non-conductive state. With this scheme, current is only flowing through the transistors when they are fully “on”, and doing useful work transferring energy to the output of the supply. The power dissipation within the transistor that would normally occur during the switching interval has effectively been eliminated. (See Figure 2.) Unwanted high-frequency voltage and current transients during the switching period – the culprits that supply much of the RF noise radiated and conducted out of the power supply – are also dramatically reduced due to the smooth resonant transition. With the noise effectively reduced at its source, enhancing filtering at the input and output of the unit ensures that the unit is well within the noise limits set by international standards.

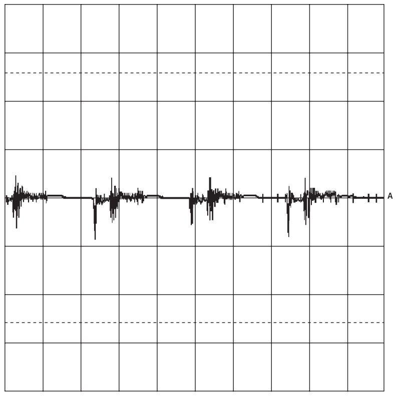

Figure 2. “Soft Switching” topology power supply with the same rating as that in Figure 1. Power loss waveform for a bridge MOSFET (320 W/div). Instantaneous peak power is now reduced to less than one-quarter the level in the “hard switching” version.

With “soft switching” techniques, reduction in wasted power will often improve the efficiency of a unit by more than 2%. While this does not sound significant, it can account for a saving of more than 20 W in a 1000 W power supply. This 20 W is power that would have been dissipated by the main power transistors, the most critical and most heavily stressed semi-conductors in any switchmode power supply. Reducing the power here lowers their junction temperature, giving increased thermal operating margins and, hence, a longer life for the power supply. Not only does a “soft switching” power supply generate significantly less electrical noise, it achieves greater efficiency, longer mean time between failures (MTBF), and higher immunity to the effects of other equipment operating nearby.

About the author:

Mark Edmunds is Director, Continuation Engineering at Xantrex Technology Inc. Xantrex Programmable Power products are the industry’s most advanced programmable DC power supplies used for benchtop, production test, burn-in, ATE, bulk power and OEM applications.