Reducing Conducted Emissions

Design for Compliance

By Glen Dash
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Line-conducted emissions pass down the power line and cause interference to low-frequency communications, usually by reradiating from the mains. For this reason, line-conducted emissions are regulated below 30 MHz. Fortunately, diagnosing and curing line-conducted problems are usually straightforward procedures.

As in the case of radiated emissions, the spectrum-analyzer display should yield the clues necessary for diagnosis. Where problems exist above 10 MHz, suspect coupling of RF signals to the AC line cord. These emissions are picked up by the line cord acting as a receiving antenna. This is really a form of radiated emissions. The line cord, being a wire, acts like any other antenna, picking up these emissions and passing them down to the line-impedance stabilization network (LISN) and the associated receiver or spectrum analyzer. To cure these line-conducted emissions, concentrate on curing the radiated emissions from the cables or case, as previously described.

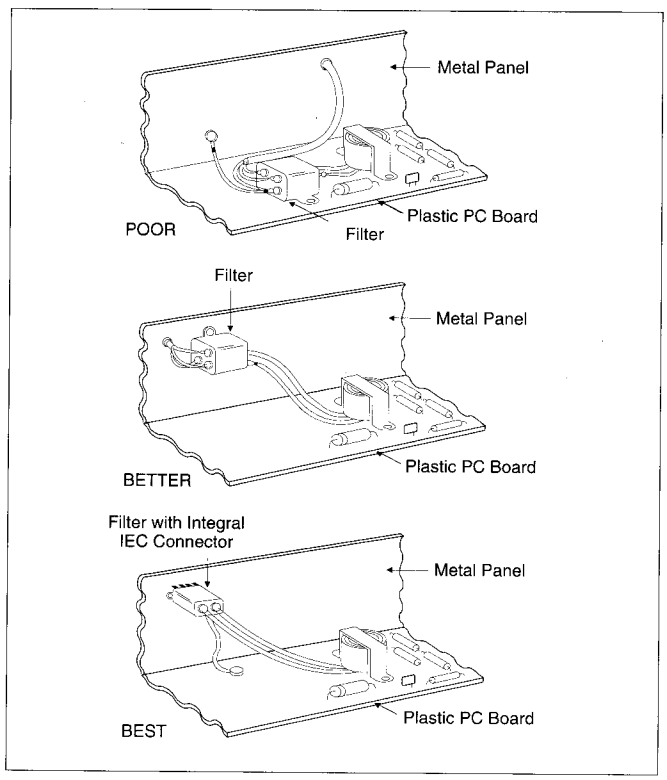

FIGURE 1: To avoid coupling onto exposed line cord, an EMI filter should be mounted carefully. Mounting it near the point where the AC line enters will minimize coupling. Integral filter connectors eliminate coupling entirely, but their small size prevents them from offering attenuation characteristics associated with large filters.

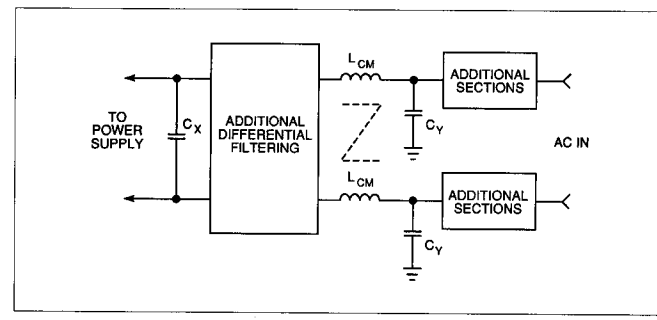

FIGURE 2: A typical single-stage filter will have line-to-line capacitor (C_x), a common-mode choke (L_{cm}), and line-to-ground capacitors (C_y). Occasionally, a multisection filter will be required.

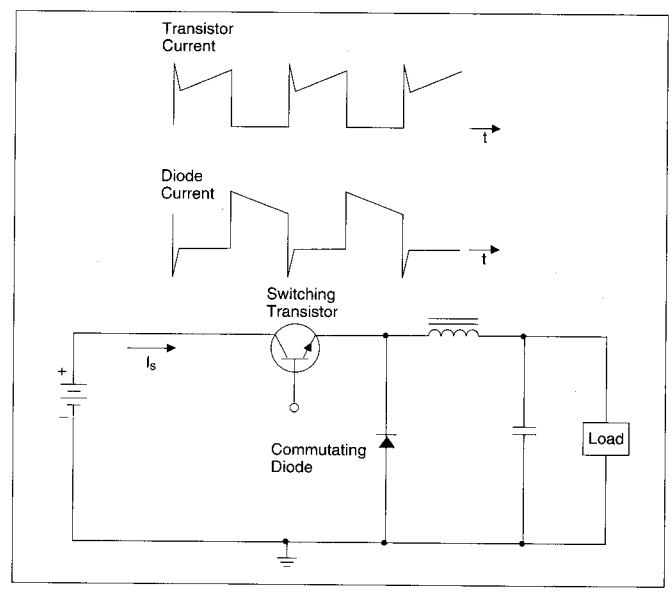

FIGURE 3: Simplified switching-mode power supply and current waveforms.

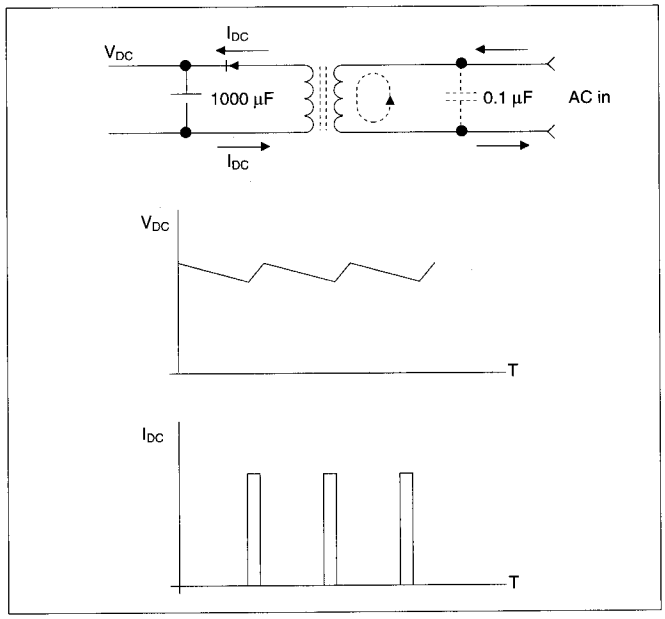

FIGURE 4: Current spikes caused by rectifier conduction can cause conducted problems up to 1 MHz. A line-to-line or "X" capacitor will eliminate most of these problems.

A second form of conducted emissions is due to logic. The same RF pulses that cause radiated emissions can pass through the power supply and down the line cord. In practice, this type of noise is not very common. Bypassing each power lead to chassis ground with a 0.001 f capacitor will differentiate diagnosis of this problem

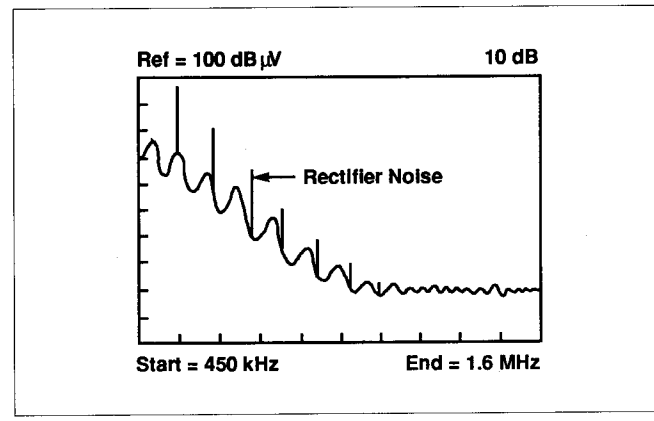

FIGURE 5: Rectifier noise. On a spectrum-analyzer display, rectifier noise appears as narrow pulses that "walk" through the display.

from that of the related problem above. One permanent and safe fix uses a line filter.

If a line filter is used, however, it must be mounted carefully. Inside a shielded cabinet, electromagnetic fields are likely to be intense. In order for a line filter to be effective, it has to be mounted near the exit point of the line cord. Integral line filters (that is, ones that have the AC outlet built in) solve this problem handily. Filters without built-in sockets can also be used but should be mounted with care. Where the AC line entrance has to be mounted some distance away from the filter, a ferrite sleeve can be placed over the line cord, near the point where it enters the chassis, in order to pick off emissions that couple onto the exposed line.

Alternatively, shielding of the internal power leads between the power entry point and the filter can keep signals from coupling to the line behind the filter.

Not surprisingly, power supplies are often a significant noise generator, especially at lower frequencies. With a switched-mode power supply, intense interference is generated at harmonics of the switching frequency. Filtering is required to contain these signals. If a line filter has not been built into the power supply, a separate line filter of substantial size will usually be required.

A filter is typically designed to suppress both common- and differential-mode signals. Filtering of each lead with respect to ground with one or more L or PI filter sections will suppress both types of interference. Sometimes the line-to-ground filtering consist simply of a pair of shunt or "Y" capacitors. Two additional types of components are also used. A bifilar wound inductor serves as a common-mode choke, acting exclusively on common-mode signals with no effect at all on differential signals. Common-mode chokes to obtain high values of inductance in a small package; since they are unaffected by differential currents due to flux cancellation in the opposing windings, they are not saturated by the incoming AC power. Also used are line-to-line "X" capacitors, which suppress differential signals by short-circuiting high-frequency signals.

In linear supplies, 60 or 120 Hz "spike" noise from diode conduction is not uncommon. The power-supply capacitors are charged when the diodes are forward-biased. An intense inrush of current occurs and shows up on the spectrum analyzer as line-synchronized impulse noise. Although a full-blown line filter will cure the problem, often a simpler measure will suffice: a line-to-line "X" capacitor of about 0.47 microfarad supplies the leading edge of the required inrush current. Where diode conduction is a problem, "X" capacitors can sometimes function successfully on the secondary side of the power transformer.