A Qualified Success: DC/DC Power Converters and EMC

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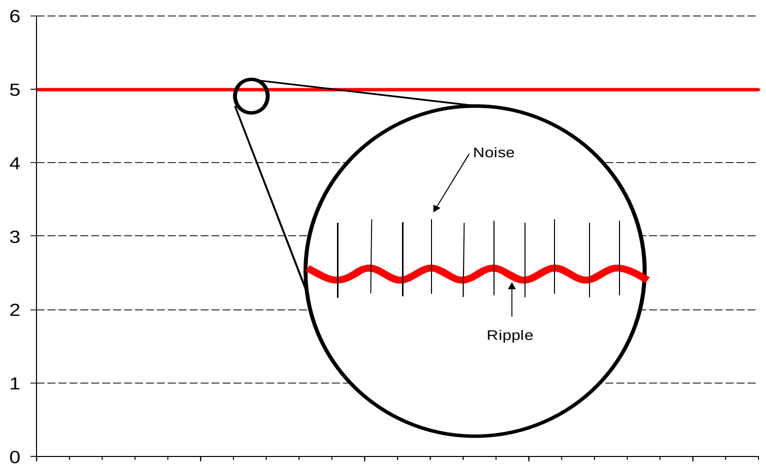
Most pieces of electronics equipment need to meet the requirements of EMC (Electro-Magnetic Compatibility) and DC/DC power supplies are no exception. However, a quick look through most DC/DC converter datasheets show that external filtering is required to meet the minimum standards required. Why is this?

Firstly, the price pressure from the market and the demand for increased miniaturization plays an important role in the development of DC/DC converters. Only the components that are absolutely necessary for operation are built into the converters and therefore only basic filtering is included in most modules. Secondly, there are two levels in the most common European EMC standard – Class A (easier) and Class B (harder), so which filtering level should be used? This is not to mention all of the other standards required by other authorities such as FCC, the military or the automotive branches – so an “universal” EMC filter that would meet every world standard would be impossible to build into a compact case design. And thirdly, multiple DC/DC converters are often used in one application, so significant cost savings can be made by using common external filter elements rather than having a full filter built into every converter.

The most commonly required European EMC Standards are called EN55022 (Information Technology Equipment: Emissions) and EN55024 (Information Technology Equipment: Susceptibility). “Emissions” concerns unwanted electromagnetic radiation from a device and is further divided into “Radiated Emissions” (where the part behaves like a small radio station and sends out electromagnetic interference which could interfere with other equipment nearby) and into “Conducted Emissions” (where the part sends out disturbances along its power supply cables that could interfere with other equipment plugged into the same supply). “Susceptibility” is the exact opposite: how robust the converter is regarding external electromagnetic interference that could interfere with its own



operation. Of the two requirements, EN55024 is relatively easy to meet by good internal design of the converter and EN55022 is the one requiring more thought.

Fig1 : Typical Ripple/Noise output waveform of a DC/DC converter

So why should a DC/DC converter generate any interference that might interfere with other equipment? Well, in every converter is a power oscillator. The oscillator takes the DC input voltage and creates an AC output that drives the internal transformer. The output of the transformer is rectified and smoothed to regenerate a DC output voltage. A close look at the output of a DC/DC converter (Fig. 1) will show two distinct waveforms superimposed on one another – the residual AC ripple on the DC output caused by imperfect smoothing of the transformer output and switching noise caused by the switching transistors. The ripple is usually at double the operating frequency and typically in the range of 100 kHz to 500 kHz. The switching spikes usually have a waveform of several Megahertz and appear at the output because of capacitive coupling within the transformer. It would be possible to use soft switching to avoid generating these spikes, but then the efficiency of the power oscillator would be too low to be commercially acceptable.

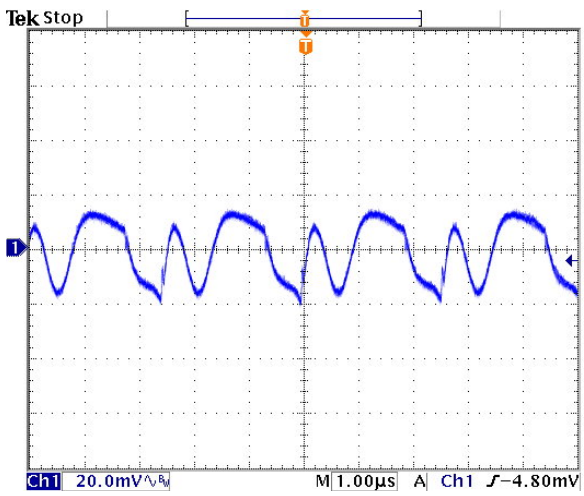


Fig.2: Reflected Ripple Current measured on the input of an RP15-A converter

Each switching cycle creates current surges on the input as energy is transferred into the magnetic field within the transformer and thence into the output capacitors and output load. These current pulsations are called the Reflected Ripple Current and can cause severe problems in meeting the required conducted emissions standards, not only because the currents can easily interfere with other equipment sharing the same supply connections but also because the input resistance converts this pulsating current into a pulsating volt drop across the input wires or tracks which can also radiate and interfere strongly with adjacent equipment.

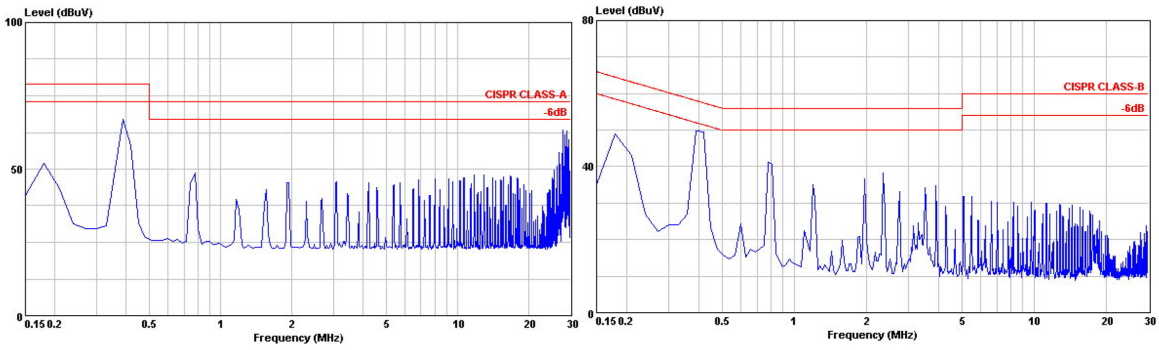


Fig 3: Typical Class A/Class B Curves for the RP15-A converter with external filter. The large peaks at low frequencies come from the power oscillator and its harmonics, the fine grass noise at higher frequencies is caused by the switching spikes. Note that the Class A scale goes up to 100dBµV and the Class B up to 80dBuV, so Class B is much harder to meet.

As mentioned previously, there are two levels within EN-55022. Which level is appropriate for your application depends on the use. Class A is required for equipment used in industrial and commercial environments and Class B also includes domestic environments. As the home environment often includes many sensitive pieces of equipment (radios, TVs, computers, games machines, etc.) or sources of electromagnetic radiation (microwave ovens or the powerful motors used in washing machines and vacuum cleaners) - all of which are used in very close proximity to one another, the requirements for Class B are actually higher.

Designing an external filter to ensure that a DC/DC converter meets the requirements is probably best explained using a concrete example – in this case Recom's sub-miniature RP15-A series. The RP15-A, and the wide input voltage range version the RP15-AW, are both housed in a 1" by 1" case which is half the size of the industry standard 2" x 1" enclosure. This sub-miniature design has advantages and disadvantages for EMC. The short tracks between components on the internal PCB means that the critical interference-generating components have good, low impedance paths to the ground and power supply pins which helps to reduce the interference they produce, but the small case size leaves little room for built-in filtering components on the input and output.

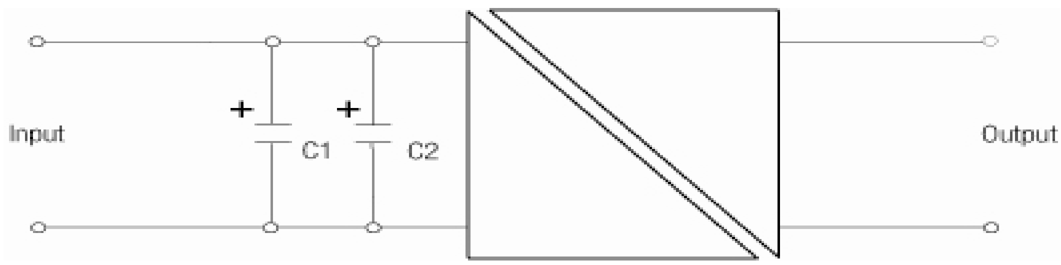


Fig4: RP15-A Class A Filter suggestion

The above external filter will meet the Class A requirements for EMC. All that is required is two additional capacitors across the input pins. The smaller capacitor C2 absorbs the high frequency noise that is radiated internally and picked up by the input pins which act as antennas. The larger reservoir capacitor C1 dampens down the reflected ripple current. The metal case and careful internal design means that the EN55024 (susceptibility) Class B standard is no problem for this converter. Typical values for C1 and C2 are 6.8µF and 2.2µF

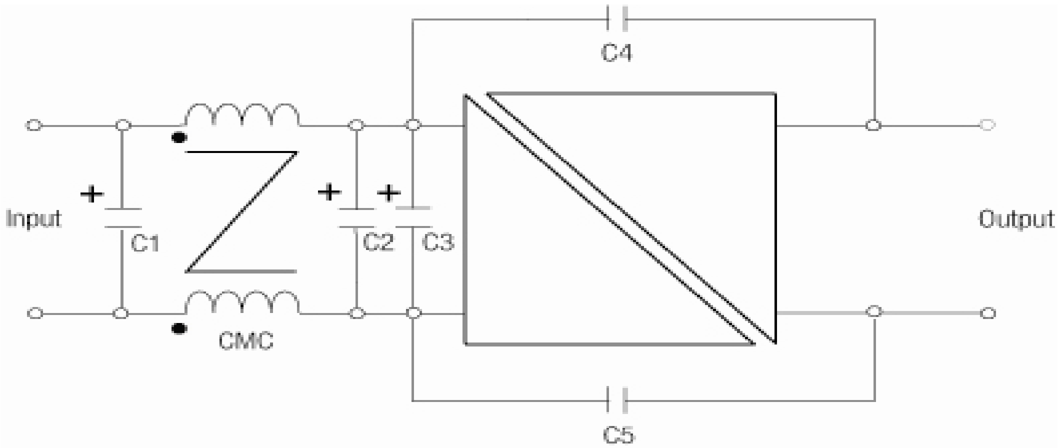


Fig5: RP15-A Class B Filter suggestion

This Class B filter is much more complicated than the Class A solution and shows how much more circuitry is required to meet the more demanding Class B requirements. The small 100nF input capacitor C3 close to the input pins fulfils the same function as in the Class A filter design, but the single larger capacitor now has to be replaced by a Pi filter consisting of two capacitors and a common mode choke. The common mode choke is an inductor with two windings wound in the opposite direction. This has two advantages: any common mode interference that appears simultaneously on both input pins with still be filtered out and a ferrite with higher permeability can be used without worrying that the magnetic core will saturate because the magnetic fields generated by the currents flowing from the supply and back to ground cancel out. C3 and C4 fulfill the important function of conducting the output noise back to the low impedance inputs. These capacitors are placed across the isolation barrier within the converter so have to be rated at the full test isolation voltage of 1600V minimum. Typical values are 6.8µF for C1 and C2, 470pF for C4 and C5 and 2x325µH for the common mode choke.

However, both of these filter suggestions will be less effective if the PCB layout in the application is not carefully done. Low impedance paths to both the supply voltage and in particular to the ground reference are essential for good EMC design. Thus, if the converter is mounted on a daughter board with only two pins on the connector carrying the supply voltage, it can be expected that EMC qualification will be problematic. Similar problems can occur if the tracks carrying the supply voltages pass through high-impedance vias from one side of the board to the other or if the track lengths are very long. Large copper ground planes, multiple vias and careful layout are also required for an effective EMC design. If done correctly, the results of these filter suggestions can be reliable, effective and involve minimum additional costs –both in the choice of filter components and in the cost of getting the EMC qualification test reports. In short, your design will be an EMC qualified success!