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RF filtering the mains

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RF filtering the mains

Keith Armstrong offers some advice on best practice when fitting mains filters to cabinets and highlights some of the common pitfalls

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Cabinets often need to be fitted with mains filters. This could be because some of the units in the cabinet are not sufficiently immune to the mains-borne electromagnetic (EM) noises present at their installation, or because the total mains noise emitted by the units in the cabinet causes interference with other equipment in the installation.

Emissions tests under the EMC Directive 2004/108/EC (listed at: http://ec.europa.eu/enterprise/newapproach/standardization/harmstds/reflist/emc.html) check that the EM noises emitted via the cabinet's mains electricity supply connection does not exceed specified limits and so are unlikely to interfere with other equipment. The immunity tests expose the cabinet to specified levels of a range of typical mains-borne EM noises – and check that it continues to work well enough. Mains filters are often needed to pass these tests.

In real life, the mains supply usually has an impedance that is far from 50Ω, and relying only the attenuation curves for 50Ω input and 50Ω output (often the only data provided by distributors) can result in disappointing performance, sometimes even *amplifying* noises instead of attenuating them! The first time this happens to you is a very unwelcome surprise.

So it is best to assume that a mains filter's attenuation at a given frequency is no better than the worst-case of all of its six attenuation versus frequency curves: common-mode and differential-mode attenuation (sometimes called 'asymmetrical' and 'symmetrical'), each mode tested with 50Ω input 50Ω output; 100Ω input 0.1Ω output, and 0.1Ω input 100Ω output. Good filter manufacturers provide all six curves for the whole frequency range of interest, which should include the conducted range (down to 150kHz or less) *and* the radiated range (up to 100MHz or more, preferably at least 1GHz).

The best mains filters have *seamless* metal bodies that include flanges or other fixing methods. To achieve anything even approaching their specified attenuation their flanges (or other fixings) must be directly electrically bonded, metal surface-to-metal surface, to an RF Reference in the cabinet. The RF Reference must achieve very low impedances at the frequencies to be filtered, and filters must be bonded to it at two widely spaced points *at least*. (Page 8 in the July 2007 issue of PSB gives a brief introduction to RF References.)

Simple cable-mounted ferrite filters can be useful where the available RF Reference does not achieve sufficiently low impedances. However, they cannot be relied upon to provide more than a few dB of attenuation, and only then at frequencies above 10MHz.

Filters should generally be fitted where a mains cable first enters the part of the cabinet controlled by an RF Reference (e.g. its backplate). For an EM screened (shielded) cabinet, the RF Reference begins at its external metal surfaces, so that is where the filters should be mounted. (Even low-cost, unshielded industrial cabinets can give better EMC if treated as if they were shielded types.)

The length of mains cable that enters a cabinet to connect to a filter should be very small, preferably less than 100mm – and should be routed well away from any other cables, and close to the RF Reference along its length. In a shielded cabinet, even 10 or 20mm of unfiltered mains cable penetrating inside can ruin its (costly) shielding effectiveness, so bulkhead-mounted filters are preferred because their unfiltered cables do not penetrate the cabinet at all. Examples of bulkhead filters include the IEC 320 'appliance inlet', and a variety of high-performance tubular 'feedthrough' devices that filter one mains conductor at a time (see Figure 1).

A wide range of chassis-mounted filters are available – often very cost-effective for currents above 10A – but as they are not bulkhead-mounting some external mains cable must enter the cabinet to connect to their terminals. The resulting poor cabinet shielding effectiveness can be recovered, at least partly, by fitting a 'Dirty Box' as shown in Figure 1. This is an essential technique when using chassis-mounted mains filters in shielded cabinets.

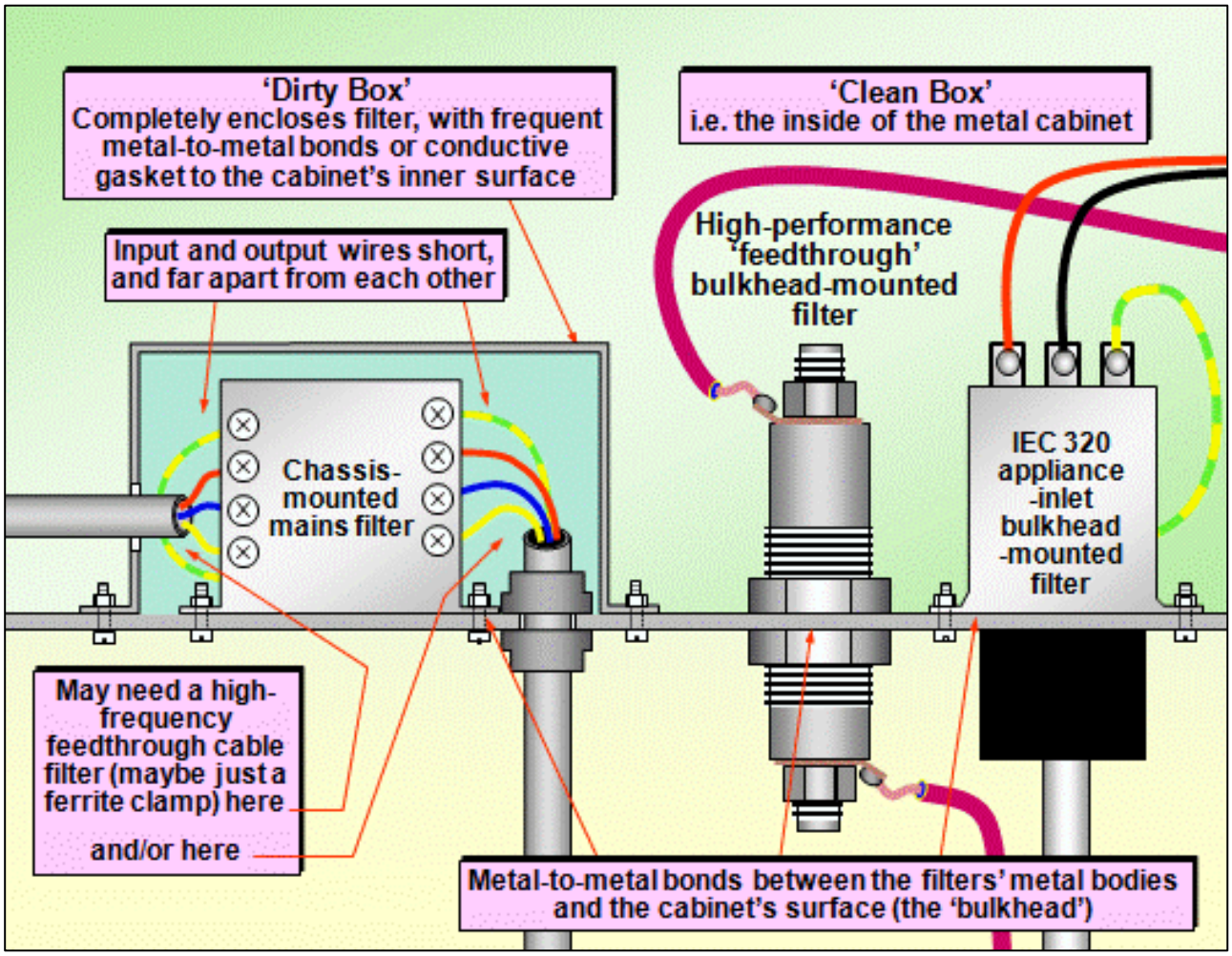

Figure 1 Mounting filters in the external surfaces of cabinets

Mains filters fitted 'upstream' of mains switches or door isolators will remain live when the cabinet is switched off by its own controls. They must have touch protection and appropriate safety warnings for the relevant terminals, to comply with the requirements of the appropriate safety standard(s).

For more details on good practices for mains filters, and other practical EMC design and construction issues, read: "*Good EMC Engineering Practices in the Design and Construction of Industrial Cabinets*", from http://www.reo.co.uk/members.php, after a simple and free registration as a 'member'.

Similar filtering techniques can be applied at system and installation level, and are described in "*EMC for Systems and Installations*" (Newnes, 2000, ISBN 0-7506-4167-3, www.bh.com/newnes, RS Components P/No. 377-6463).

For those who wish to investigate further, the Directives and Regulations, and their official guides, plus a great deal of useful and practical information, are available as described in the document: '*Some Useful References on EMI and EMC*' posted on this site.