HIGH PERFORMANCE 400Hz POWER FILTERS MEETING 100dB AT 14kHz

There are two main considerations when designing high performance filters for use on 400Hz supplies. The first relates to attenuation in the pass band and the second relates to power dissipation of filter capacitors and inductors at 400Hz and at harmonics of 400Hz.

1. Attenuation Considerations

Most power line filters are based on simple pi or multiple pi filter circuit designs. The attenuation slope of such filter circuits will be 6dB per octave per element or 20dB per decade per element.

The attached graph shows the slopes provided by a 3 element, a 5 element and a 7 element filter in order to meet 100dB at 14kHz.
It can be seen that the 3 element filter would have a significant attenuation at the fundamental frequency of 400Hz which is unacceptable. The graph also shows, for comparison, that a 3 element filter meeting 100dB at 100kHz would not attenuate the 400Hz fundamental.

The more complex 5 and 7 element filters meeting 100dB at 14kHz do not have any attenuation at the fundamental frequency of 400Hz but they do have significant attenuation at the harmonic frequencies. Although this may not be a problem as far as the filter performance is concerned, it will have implications on filter power dissipation.

The above discussions are based on a simplified approach to give an easy comparison of filter circuits. They do not take into account system impedance considerations or resonance effects.

2. Filter Power Dissipation Considerations

Filter capacitors will normally be connected from each line to earth. These capacitors will be designed to conduct the normally expected leakage current at 400Hz but they will additionally have to conduct currents resulting from voltage harmonics on the supply. These currents can be very substantial because of the reduced capacitor impedance at harmonic frequencies. The capacitor current, I, for a capacitor of capacitance, C, at each harmonic frequency, f, and harmonic voltage, V, will be given by

$$I = 2\pi fCV$$

The capacitor heat losses will then be VI x capacitor dissipation factor for each harmonic.

Losses similarly affect the filter inductors and will be based on the magnitude of current harmonics flowing through the inductors.

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Referring again to the graph, it would appear that the 7 element filter meeting 100dB at 14kHz would be more suitable for a 400Hz supply than a 3 element filter meeting 100dB at 100kHz. In practice, however, this is not the case because the 7 element filter will have a much larger total capacitance and inductance so its heat losses will be much higher.

Under ideal conditions with harmonics less than say 0.5%, a normal 5 or 7 element filter should be an acceptable solution to meet 100dB at 14kHz.

However, it is our experience that 400Hz supplies are notoriously bad for harmonics. The harmonics normally increase when load is applied and rarely comply with claimed figures. We have measured the harmonic content of several 400Hz supplies on-site. These were all claimed to have a low harmonic content but were found to be very bad when measured and would have given overheating problems with most designs of filter meeting 100dB at 14kHz.

We have also had numerous reports and requests for advice from concerned customers with 400Hz filters from other manufacturers which are overheating, probably due to harmonics not being considered or being greater than anticipated.

We have successfully designed and supplied special 400Hz filters with higher performance than our standard catalogue range. These special designs have to be substantially larger than standard designs to allow them to dissipate the extra heat generated by the harmonics. For this type of application, we would always recommend trial of a prototype under real operating conditions, to verify harmonic content and confirm filter suitability for reliable long term operation.

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Conclusions

1. Under normal circumstances for supplies with less than 3% total harmonic distortion, we would recommend our standard catalogue range of filters meeting 100dB at 100kHz.

2. Where higher performance is essential, we may be prepared to design special filters capable of handling harmonics known to be on the supply. Before doing this, we would require the following information:-

a) Worst case voltage harmonics under all load conditions.

b) Worst case current harmonics under all load conditions.

c) Harmonic analysis of a) and b) to highlight the significant voltage and current harmonics.

d) Indication of source and load impedances of system, if known.

e) Maximum current loading for which the filter is to be used.

Where practical, we would recommend purchase of a prototype to verify the above parameters under actual operating conditions and confirm acceptable temperature rise on filter.

We could not accept liability for overheating caused by harmonics not advised to us.

We would also point out the high levels of leakage current to earth associated with such filters both from a safety point of view, and because of the extra current required to be supplied by the generator.

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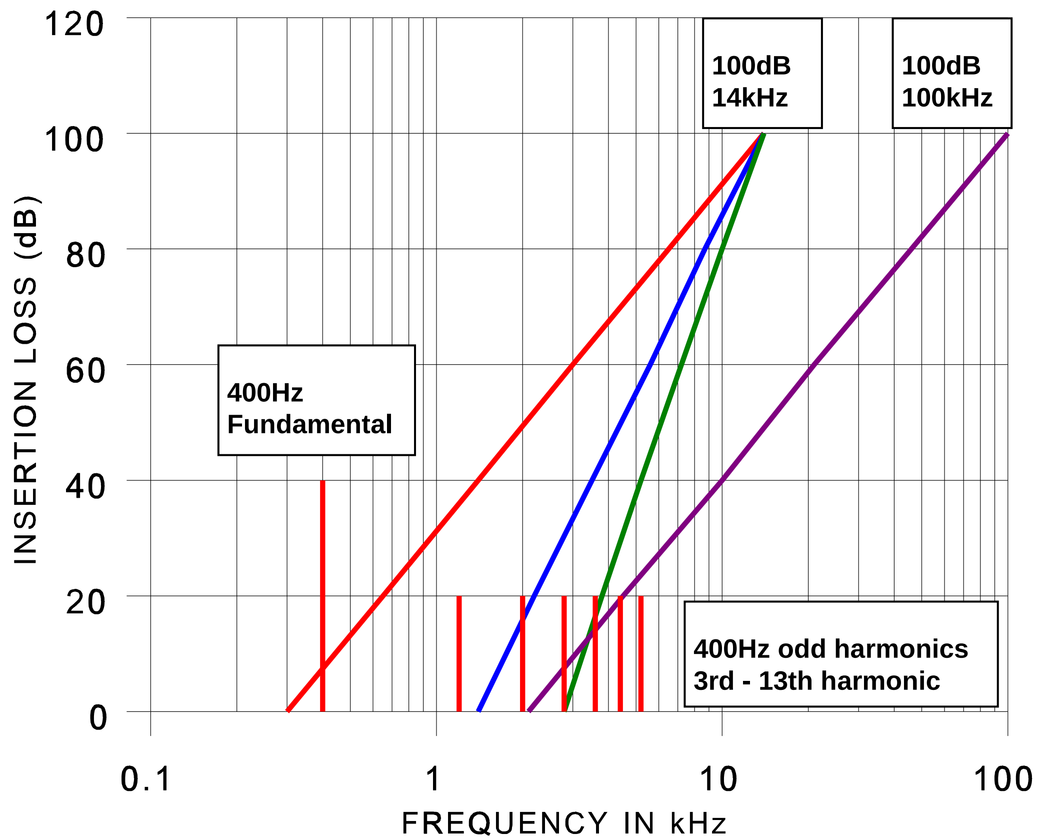
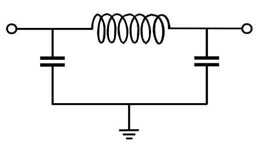
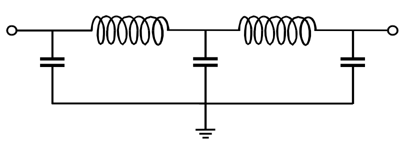
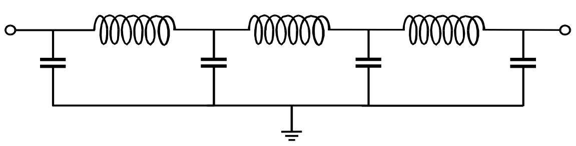
COMPARATIVE SLOPE PERFORMANCE OF FILTERS



Slope performance
3 element filter
5 element filter
7 element filter
3 element lower performance


3 element filter


5 element filter


7 Element Filter

This information is for guidance only

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