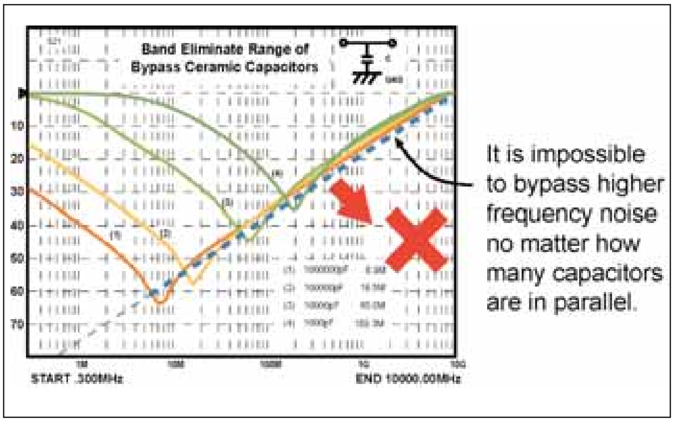
# EMI Filters Using Parallel Capacitors

How many times have you designed an EMI filter for a particular system and had it fail the specified test limits at some upper frequency? I will tell you that I sure have. One of the most obvious fixes is to parallel existing capacitors. So, you can calculate the required capacitor value (or as most do - guess) the following way is shown below. Then parallel it with the existing capacitor. After adding this fix, as the analyzer sweeps over the troubled frequency area, the troubled area is fixed! Except, as the sweep continues over the rest of the range, you note that there is now an area out of specification that passed the earlier test. The question is, why?

The graph below is from a company in Taiwan, UWB Technology, that designs high frequency very wide band EMI filter components. This company has a patent on these items. The following graph shows that the same style of capacitor of various values has the same Self Resonant Frequency (SRF) line or slope. As the capacitor value gets smaller, the SRF value is at a higher frequency, but with less loss.




Above the SRF point (the peak of each curve), all the capacitors are inductive. Take the two larger capacitors (brown and yellow traces) and note where the two traces cross. At the cross point, the brown trace is inductive and the yellow is still capacitive. This becomes a parallel resonant tank circuit. The capacitors shown here are very small high frequency components of the same type, style, and material and this cross point would be close to 12 MHz. This feature is true for any two traces, approximately resonant at the cross point frequencies. This parallel Tank offers very high impedance and the 3 dB width points are a function of the tank circuit Q.

Actually, this phenomenon can happen between any two capacitors regardless of style or type. Just the curves would be different than the curves above. I have seen required losses at 150 kHz and a 2.2 uF capacitor was required to meet this loss and find that the circuit failed at 350 kHz. So, this area is out of limits by maybe 1 dB.

To calculate the parallel capacitor value, the following is needed.

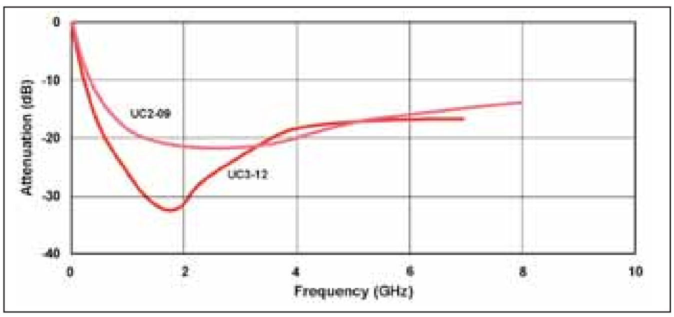
1) The frequency of the outage - here 350 kHz. (Ft)
2) How far above the limit - here by 1 dB. (A)
3) The impedance - typically 50 Ohms at this frequency. (R)
4) A capacitor gives 6 dB of loss per octave. (B)

The simple equation is:

$$C = \frac{2^{\left(\frac{A}{B}\right)}}{2\,\pi F_T\;R} = \frac{2^{\frac{1}{6}}}{2\,\pi\;350000\;x\;50} = 0.01\,uF$$

A 0.01 uF wrap and fill film capacitor would parallel the existing capacitor and, as the sweep moves across this 350 kHz, all looks well. But as the sweep moves to the higher frequencies, the requirement was out at 1,250 kHz by 6 or so dB, all because of a parallel tank circuit created by the bigger capacitor being above its SRF. Granted, in this situation, the 2.2 uF could have been increased to the next bigger size and may have worked. But, most of my background has been dealing with serious losses requiring 80 dB at 20 kHz. These often require 20 uF capacitors and simply going to the next size may be unrealistic due to size and value.

UWB Technology has developed some nice ways to decouple these high frequency capacitors that clean up the noise on power feeds and reduce the effect of SRF. This product has a very high band with starting, depending on which unit and topology, 50 MHz well into the GHz range and offers as much as 30 dB. This product has applications for ASICs, RF modules, clocks, cell phones, power line communications, and many more. Even SMPS now with switching frequencies approaching 500 kHz and the rise times in the ns range create very high harmonics that this product greatly reduces or eliminates. I am to give a presentation in Denver at the 2008 Magnetics Conference. I hope to see you there.

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