# Power Tip #4: Damping an Input Filter ” Part 2 of 2

By Robert Kollman, Texas Instruments 09.29.2008 0

(*Editor's Note:* To see a linked list of all entries in this series, click **< http://> here < https://m.eet.com/media/1055127/PowerTipSerieslist.pdf>** .)

In Power Tip #3, we discussed how the source impedance of an input filter can turn resistive, and how it can interact with the negative input impedance of a switching regulator. At worst case, these impedances can be equal in magnitude, but opposite in sign to make an oscillator. A general criterion has been established that the source impedance of an input filter should be at least 6dB less than the **input < http://www.powermanagementdesignline.com/encyclopedia/defineterm.jhtml?term=input&x=&y=>** impedance of a switching regulator as a safety margin to minimize the chance for oscillation.

The design of an input filter usually begins with selection of an input capacitor (CO of Figure 1) based on ripple current rating or hold-up requirements. The next step usually involves selecting an inductor (LO) based on the system's EMI requirements. As we saw last month, near resonance the source impedance of these two elements can be quite high, leading to an unstable system. Figure 1 presents a method to control this impedance by placing a series resistor (RD) and **capacitor < http://www.powermanagementdesignline.com/encyclopedia/defineterm.jhtml?term=capacitor&x=&y=>** (CD) in parallel with the input filter. The filter could be damped with just a resistor across CO. However, in most cases the power loss would be unacceptable. An alternative method is to add a series connection of an inductor and resistor across the filter inductor.

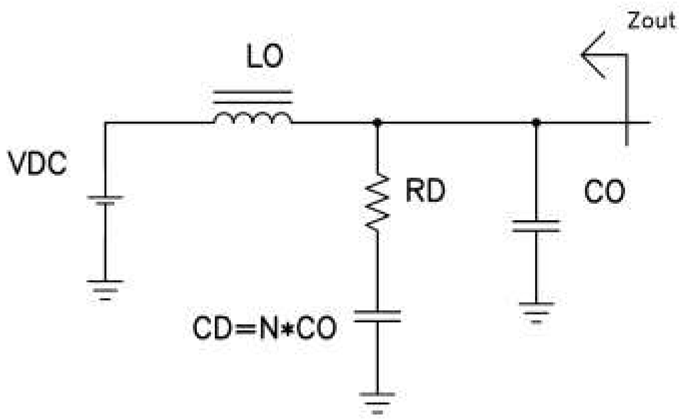


*Figure 1: CD and RD damp the* ***output < http://www.powermanagementdesignline.com/encyclopedia/defineterm.jhtml?term=output&x=&y=>*** *filter source impedance.*

*(Click this image to view a larger, more detailed version)*

Interestingly, there is an optimum choice of damping resistance once the four other **circuit < http://www.powermanagementdesignline.com/encyclopedia/defineterm.jhtml?term=circuit&x=&y=>** elements are picked. Figure 2 shows the output impedance of this type of filter as the damping resistor is varied. The red curve shows a damping resistor that is too large. Consider an extreme case. If the damping resistor was open, then the peak would be quite high and would be set only by CO and LO. The blue curve shows a damping resistor that is too low. If the resistor was made a short, the resonance would be set by the parallel combination of the two capacitors and the inductor. The green curve represents the optimum value of damping. This value is easily found by numerical methods (Reference 1) that contain the closed form solution.

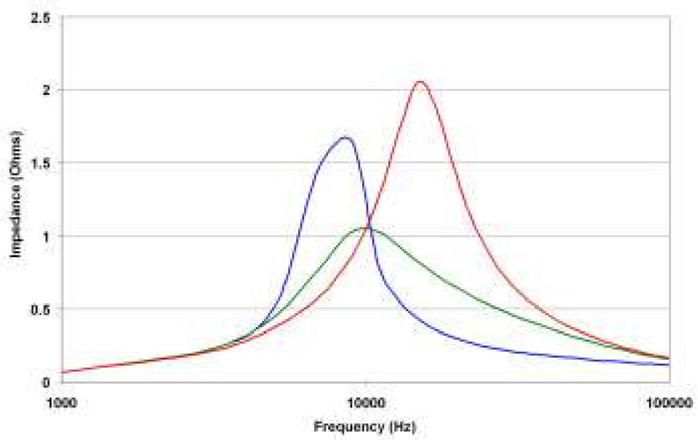


*Figure 2: For a given CD to CO ratio, there is an optimum damping resistor.*

*(Click this image to view a larger, more detailed version)*

Figure 3 can be quite useful in selecting the damping components. This chart was prepared using the closed form solution developed by RD Middlebrook. The abscissa is the ratio of the damped filter output impedance to the characteristic impedance of the undamped filter ($ZO = (LO/CO)^{1/2}$ ). There are two ordinate values: the ratio of damping capacitor to filter capacitor (N); and the ratio of the damping resistor to the characteristic impedance. To use this chart, first pick LO and CO based on circuit requirements to establish ZO. Next, establish your maximum input filter source impedance by dividing the minimum **power supply < http://www.powermanagementdesignline.com/encyclopedia/defineterm.jhtml?term=power supply&x=&y=>** input impedance by two (or 6dB).

The minimum power supply input impedance is equal to $Vinmin^2/Pmax$. This lets you calculate an abscissa value. Then simply read the ratio of the damping capacitor to the filter capacitor, and the ratio of the damping resistor to the characteristic impedance. For example, a filter with a 10µH inductor and a 10µF capacitor will have a characteristic impedance of $Zo = (10µH/10\ µF)^{1/2} = 1$ Ohm. If it were filtering a 12W power supply with 12V minimum input, the power supply input impedance would be $Z = V^2/P = 12^2/12 = 12$ Ohms. The maximum source impedance should then equal half that, or 6 Ohms. Now enter the chart on the x-axis at 6/1 = 6. Then read CD/CO = 0.1 or 1 µF and RD/ZO = 3, or 3 Ohms.

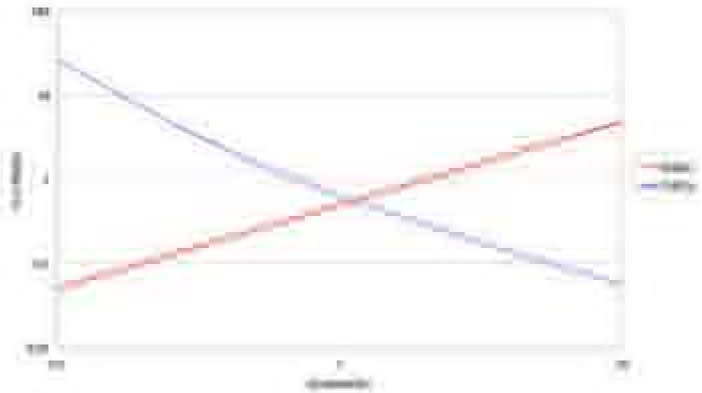

*Figure 3: Once you pick LO and Co, choose CD and RD from maximum allowable source impedance.*
*(Click this image to view a larger, more detailed version)*

In Power Tip #5, we will discuss using a buck **controller < http://www.powermanagementdesignline.com/encyclopedia/defineterm.jhtml?term=controller&x=&y=>** in a buck-boost power supply.

Reference


1. R.D. Middlebrook, "Design Techniques for Preventing Input-Filter Oscillations in Switched-Mode Regulators," Proceedings Powercon 5, 1978.


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