Power Tip #3: Damping the input filter — Part 1

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

While switching regulators are often preferred over linear regulators because they are more efficient, the switching topology leans heavily on an input filter. This circuit element, combined with the supply's typically negative dynamic impedance, can contribute to oscillation issues. Here's how to avoid the problem.

All supplies generally maintain their efficiency over a given input range. Thus the *input power is more or less constant* with the input voltage level. Figure 1 shows a the switching supply's characteristics. As the voltage is reduced, the current increases.

(Click on image to enlarge)

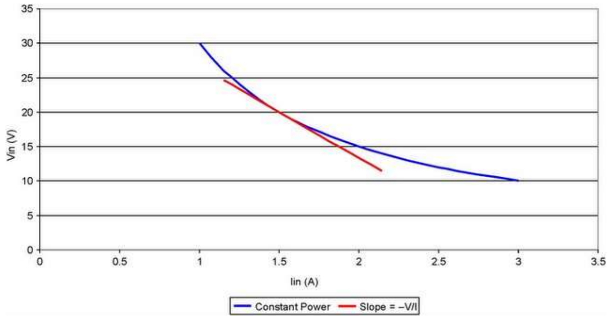

Figure 1: A switching power supply presents a negative impedance

Negative input impedance

This voltage-current line has a slope that essentially defines the dynamic impedance of the power supply. The slope of this line is the negative of the input voltage divided by the input current. That is, with $P_{in} = V \cdot I$, we have $V = P_{in} / I$; and so $dV/dI = -P_{in} / I^2$ or $dV/dI \sim -V/I$.

This approximation is a bit of an over-simplification because the control loop impacts the frequency response of the input impedance. But many times, this simplification is good enough when current-mode control is involved.

Why there's an input filter

The switching regulator's input current is discontinuous, and if the input current isn't filtered it can disrupt system operation. Most power systems incorporate a filter of the type shown in Fig. 2. The capacitor provides a low impedance for the switching current in the power stage. The inductor provides a high impedance for the resulting ripple voltage on the capacitor. The filter's high impedance minimizes switching current flow into the source. At low frequencies, the filter's source impedance is equal to the inductor's impedance. As you increase frequency, the impedance of the inductor increases. At very high frequencies, the output capacitor shunts the impedance. At the mid frequencies, the inductor and capacitor essentially form a parallel resonant circuit, and thus the source impedance is high, and resistive.

In most cases, the peak source impedance can be estimated by first determining the characteristic impedance of the filter (Z_o), which is equal to the square root of the inductance divided by the capacitance. This is the impedance of either the inductor or the capacitor at resonance. Next add the capacitor's equivalent series resistance (ESR) and inductor's resistance. Then find the *Q* of the circuit. The peak source impedance is equal to approximately Z_o times the *Q* of the circuit.

(Click on image to enlarge)

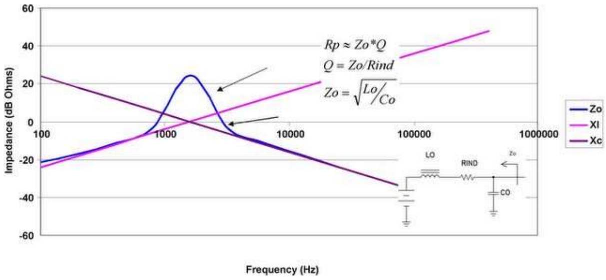

Figure 2: At resonance, the filter's impedance is high, and resistive

Oscillations

But the switcher's resonant filter, coupled with the supply's negative impedance, can present problems. See Fig. 3, which shows two resistors of equal value and opposite sign in a voltage-driven series circuit. Under such conditions, the output voltage tends to infinity. You have a similar situation in a power system where you have the negative resistance of the power supply being sourced by the equivalent resistance of the input filter at resonance; in this case, the circuit will tend to oscillate.

(Click on image to enlarge)

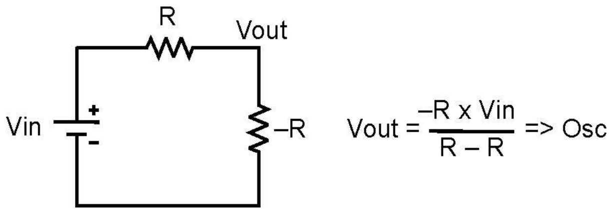

Figure 3: The switcher's resonant filter coupled with its negative impedance can create unwanted oscillations

The secret to making stable power systems is to ensure that the source impedance of the system is always much less than the power supply's input impedance. This objective needs to be achieved at minimum input voltage and maximum load (i.e, the lowest input impedance). In *Power Tips #4* , we will discuss some practical methods of controlling the source impedance.

The *Power Tips!* series
#1, July : **Picking the right operating frequency for your power supply < http://www.powermanagementdesignline.com/howto/powersupplies/208802819>**
#2, *August* : **Taming a noisy power supply < http://www.powermanagementdesignline.com/howto/powersupplies/209902227>**

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