BY HOWARD JOHNSON, PhD

Series resonance in power systems

Many digital systems suffer excessive power-supply noise at frequencies relating to the system clock. Could a series-resonant circuit, such as the one in **Figure 1**, connected between the power and the ground planes attenuate that noise? The answer can be yes, but only if your circuit satisfies the following improbable conditions.

First, the frequency of the system clock must remain fixed. In systems without a crystal-controlled clock, the clock frequency may wander ±30% or more. Low-power systems often slow the clock to conserve power when idle. High-performance systems sometimes come in speed variants, for which customers pay extra to gain performance. As a diagnostic test, a designer may slow the system clock to reveal certain timing-related failures. No power-supply-noise-mitigation strategy employing careful tuning of exact noise frequencies can possibly work under these conditions.

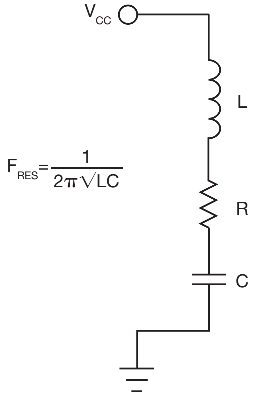

Figure 1 The impedance of this network attains its smallest value at the resonant frequency.

The allure of a series-resonant circuit is that it permits the use of a smaller value of capacitor than otherwise might be necessary *if* you match that capacitor with appropriate values of inductance and resistance, creating the series-resonant effect. Unfortunately, the smaller the capacitor, the more precise the circuit must become.

For example, a capacitor of one-fifth the ordinary value requires capacitor and inductor components with ±10% tolerance. A capacitor of one-tenth the normal value requires ±5% tolerance, and so on. It is difficult to implement high-frequency inductors with such tight tolerances. If you think of the layout inductance as fixed and plan a smaller value of capacitance to place the series-resonant point at a favorable location, you will face the same difficulty: You cannot easily control the exact values of capacitance and inductance.

The clock must play continuously, repeating forever without stops or gaps. If the clock stops, your resonant circuit will spin on, plunging out of control, creating disturbances just as bad as the problem you were trying to mitigate. When the clock restarts, the resonant circuit takes many cycles to catch up—providing zero benefit during that period. A resonant circuit is useful only with continuous stimulation. It is powerless to prevent noise from random data events.

You must place the series-resonant circuit within a small fraction of one wavelength of any device that it is protecting. Within that limited radius, the spreading inductance of the power and ground planes modifies the effective series inductance of the resonant circuit. Consequently, the exact positioning of a resonant circuit matters tremendously, so you cannot alter the layout without implementing a complete redesign. Even worse, a resonant element that provides substantial attenuation for clock noise emanating from one location may provide no benefit or may even exacerbate the noise from another source.

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Last, remember that a resonant circuit attenuates noise at only one frequency. It provides little or no benefit at other harmonics of the clock rate. In a sinusoid-based system, such as an FM or an AM radio, resonating power-supply components can provide truly astonishing benefits.

In a digital system that starts and stops at various clock speeds and in which the layout constantly changes from one version to the next, the use of resonating power-supply-filter elements does not pass the KISS (keep it simple, stupid) test. A digital-power system is better served by lots of large, simple, nonresonant bypass capacitors.**EDN**

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