BY HOWARD JOHNSON, PhD

Quality factor

What matters most in a capacitor depends entirely on how you use it. For example, capacitors in the Electra pulsed-power fusion-ignition system require a voltage rating of at least 5 million volts, with an incredible energy-storage density. Solution? Build a massive coaxial structure and fill it with water (**Reference 1**).

A 1V switching power supply has vastly different requirements. This design needs capacitors with low ESR (equivalent series resistance). Switching power designs surge huge currents through the capacitors, back and forth, constantly charging them up and down. Even a tiny amount of series resistance in the presence of all that surging current can overheat, possibly bursting the package and spilling dielectric goo all over your board. I have been around systems that actually erupt in flames when that happens. To reduce the ESR at switching-power-supply frequencies, thick copper plates, firmly bonded to the lead frame, really help.

Capacitors in narrowband filters need a high Q, or quality factor. This number, which is closely associated with the dissipation factor, determines how long a resonant circuit will ring. To make highly resonant, ringy circuits, you need high Q. Low-noise oscillators, IF filters, and many other circuits need high-Q capacitors. To make a high-Q capacitor at microwave frequencies, you reduce the skin-effect resistance of the leads and plates using silver-plated construction and specify an expensive, low-loss dielectric.

Specifications having to do with initial tolerance, temperature drift, and long-term stability govern the inherent accuracy of your circuits. These specifications require stable, accurately machined dielectric materials. Properly aged, low-dielectric-constant ceramic materials fit this bill.

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If you need a specific, well-known value of temperature coefficient to compensate for a problematic temperature drift in another part of your circuit, other dielectric materials are available to do that job. Imagine how low the volumes must be (and how high the prices) on these types of specific parts!

Now comes the application I care most about: bypass capacitors for high-speed digital products. Depending on your power-system architecture, these bypass capacitors must cover a range of frequencies—from a few megahertz to several hundred megahertz, providing a low-impedance connection between power and ground all across that band. For that purpose, pick the smallest package (smallest inductance) your manufacturing people will let you use, and in that package size choose the largest value of capacitance you can reliably purchase from multiple vendors.

For this application, you do not need high voltage, low ESR, high Q, or great stability. Ignore those parameters. Especially, do not pay extra money for "microwave-grade" high-Q capacitors; ordinary, garden-variety, low-Q capacitors will work better in your digital application. High-Q capacitors exacerbate resonances in a circuit, and resonance is the last thing you need in a power-distribution system. Digital folks want low-Q capacitors.

Taking the "low-Q" insight one step further, it would be great if you could purchase capacitors that *guarantee* a low quality factor (a *minimum* value of ESR). To help make that situation possible, well-respected power-system designer Istvan Novak will lead a TecForm discussion at DesignCon 2006 in Santa Clara, CA, looking into ways of making low-Q, high-ESR capacitors. I wish him the best of luck at that session, as low-Q construction is something from which we all could benefit. EDN

REFERENCE

1 www.ge-prize.com/Laureates/jan/lecture/.

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