Parasitic Inductance of Bypass Capacitor II

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Wow! This Fall has been a B-U-S-Y quarter, taking me on trips to California, Massachusetts, Arizona, New Mexico, Colorado, and Malaysia. It's great to return home for a quiet, and restful, holiday season.

Our Thanksgiving turkey turned out beautifully this year. The cheap Wal-Mart smoker on the back porch takes frequent tending to keep the fire going in its little smoke box, but the results justify the means. After spending twelve hours smothered in apple-wood smoke and maple-flavored sauce our 22-lb turkey turned an incredibly deep reddish hue, delighting our guests who had never before enjoyed a barbequed turkey. To top it off, it snowed the next day so the kids all got to go sledding.

On a completely different subject, I'd like to say thanks to everyone who has developed an interest in my latest book, High-Speed Signal Propagation.

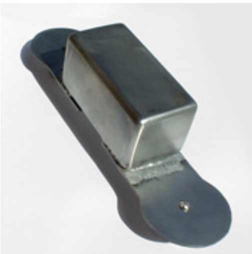
If my books have influenced your career in a positive way, please take a moment to document your thoughts at the Amazon.com web site. Other engineers would like to hear what you have to say. To enter a comment, go to www.amazon.com , search for "High-Speed Signal Propagation" or "High-Speed Digital Design", and then scroll down until you see a button that says, "Spotlight Reviews: Write an online review and share your thoughts with other customers." Even if you didn't buy your book through Amazon you can still write about it. Especially interesting are stories about differences the book made in your project work.

Parasitic Inductance of Bypass Capacitor II

The following values for the inductance of a surface-mounted bypass capacitor were collected using the step-response technique described in chapter 8 of *High-Speed Digital Design: Handbook of Black Magic*, ISBN 013395724-1, and discussed in detail during my video "Bypass Capacitor Inductance", which is shown as part of my regular class. I hope you find the numbers useful.

The measurement setup is similar to that shown in Fig. 1.11, p. 18, of *High-Speed Digital Design* (if you don't have the book, it's just a step-response test setup with a step source impedance of about five ohms).

In taking these measurements I've made two major simplifications that improve the accuracy of the result.



First, since the effective series inductance of a bypass capacitor has to do only with the shape of the conductive region (i.e., where the current goes), and nothing to do with the dielectric, I have eliminated the dielectric. The components under test in this experiment are simply blocks of solid metal, shaped to mimic the shape of the vias, mounting pads, solder fillet, and body of a surface-mounted bypass capacitor. This technique produces a physical component with the same effective series inductance as a real bypass capacitor, but no significant series resistance and no series capacitance (mathematically, the capacitance is infinite). My solid-metal-body measurement technique ignores fine details of the internal construction of the bypass capacitor. Such a technique works because the effective inductance of a practical monolithic ceramic bypass capacitor under actual conditions of use has overwhelmingly to do with the mounting configuration of its vias and pads and very little to do with the internal construction of the part. That this assumption is a good one is easily demonstrated by mounting a real bypass capacitor under ideal conditions (nearly zero-length vias, tied straight to the power-ground planes) and verifying that its inductance under those conditions is substantially less than the much larger value of inductance measured when using vias of a practical length.

The second simplification is that I used physical models at a scale 100 times larger than the real-life components I was trying to measure. This enlargement multiplies the effective inductance of the component by a factor of precisely 100, making it possible to conduct accurate measurements with ease. It also made it possible to machine the physical models without undue concern about the mechanical tolerances involved in the machining process.

In all cases the effective inductance of the component is strongly influenced by its height about the nearest plane. A good discussion of this principle, and also the influence of the planes themselves, appears in the article "Parasitic Inductance of Bypass Capacitors".

Measurements were taken on six basic layouts (Figure 1).

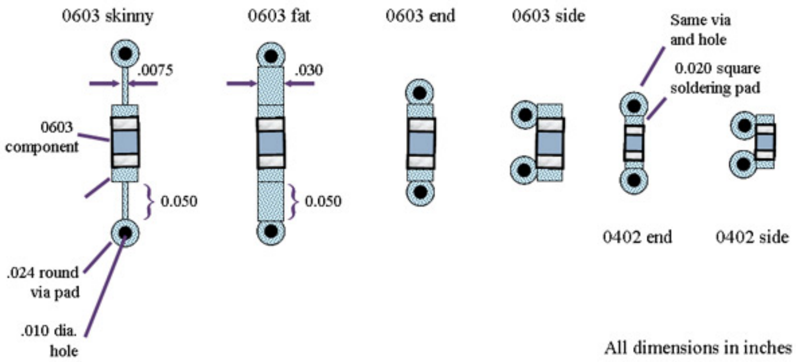


Figure 1-For measurement purposes, each layout was fabricated at 100:1 scale from type 304 non-magnetic stainless steel.

Each layout was measured first using an equivalent via diameter of 0.010-in. and then again using an equivalent via diameter of 0.020-in. In both cases a set of four different via lengths (i.e., capacitor mounting heights) were used, equivalent to real-life dimensions of: 0.004, 0.006, 0.010 and 0.020-in. (Tables 1 and 2).

Table 1-Parasitic Inductance of Bypass Capacitors, nH, hole dia. 0.010 in.

Via length	0603 skinny	0603 fat	0603 end	0603 side	0402 end	0402 side
.004	1.51	0.95	0.50	0.36	0.42	0.26
.006	1.77	1.17	0.59	0.46	0.50	0.32
.010	2.18	1.52	0.77	0.61	0.67	0.40
.020	2.87	2.23	1.16	0.85	1.01	0.60

Table 2-Parasitic Inductance of Bypass Capacitors, nH, hole dia. 0.020 in.

Via length	0603 skinny	0603 fat	0603 end	0603 side	0402 end	0402 side
.004	1.51	0.89	0.42	0.33	0.38	0.21
.006	1.66	1.12	0.53	0.38	0.44	0.25
.010	2.13	1.47	0.68	0.51	0.58	0.32

.020	2.68	2.07	1.07	0.67	0.82	0.43

Bypass capacitor inductance, layout, resonance, multi-valued arrays, and a wealth of other topics are all included in my ever-popular (and oft-revised) class, High-Speed Digital Design.

Best Regards,
Dr. Howard Johnson