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Reducing EMI/RFI Susceptibility

by Rob Derksen and Bart Bouma, Phycomp/Yageo, and Jim Muccioli and Dave Anthony, X2Y® Attenuators -- 10/1/2003
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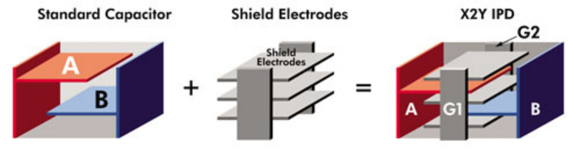

Fig. 1: Construction of the X2Y IPD
(click image to enlarge)

The number of peripherals surrounding the modern computer user continues to increase steadily. Faster technologies such as CMOS circuits are switching larger currents, but with reduced voltage margins. As clock and data speeds increase, so does a circuit's sensitivity to noise. For equipment to work together, it is becoming imperative that strict conformity with electromagnetic interference (EMI) emission limits becomes essential.

For a designer, reducing noise susceptibility and circuit impedance across a broad frequency band means reducing individual component inductance values. Design-in techniques using a new capacitor have found that a designer can fundamentally reduce the inductance to the 50 pH range while maintaining low equivalent series resistance (ESR).

This article will look at board interference, how shielding electrodes can suppress parasitics and improve broadband circuits with an X and Y capacitor design approach. This approach reduces the number of decoupling capacitors and improves performance by providing both common and differential-mode noise suppression for high-frequency signal line filtering.

A New Approach to On-Board Interference

In a conventional setting where a designer is using ferrite bead technology, the on-board interference in the design is contained by shielding the equipment case. This can mean that the leads entering and leaving the case are susceptible since they are usually acting as antennas for receiving/transmitting common mode interference. Any common mode interference due to stray inductance or capacitance from power and data leads is now generally mopped up by clipping a ferrite bead to one or both ends. The bead chokes the RFI at the point where it clips onto the lead, providing a high resistance path for the high-frequency interference. Typically, this sets up current loops that dissipate the energy as heat in the ferrite core, rather than being transmitted down the cable. In the case of power lines, the ferrite bead prevents EMI and RFI from being transmitted; and on data lines it prevents any stray interference from being received.

Ferrite beads deal fairly effectively and easily with the problem, although the EMI suppression they can achieve is limited. This can be relatively expensive, as it involves a separate assembly operation. A better approach is to suppress the noise on the circuit board itself. This demands low-inductance components — particularly capacitors — to isolate critical circuits from ripple and other high-frequency effects.

In several instances, surface-mount ceramic multilayer capacitors (MLCC) have helped reduce interference by improving decoupling performance. MLCCs with low-inductance series have been used successfully to cut interference still further. Located as close as possible to the microprocessor, it can help keep interference manageable in circuits with process and clock speeds up to approximately 1 GHz.

Above that frequency, the only successful approach is to minimize parasitic inductance and resistance of critical circuit elements. In this case, a new technology and design-in that offers low-inductance MLCCs must be accompanied, for critical circuits, by ultra-low-inductance X and Y capacitors to reduce interference on power and data lines. In the past, discrete components were used, and there is a huge advantage in integrating them by using this new technology.

Shielding Electrodes Suppress Parasitics

The new design methodology starts from a standard two-electrode (A and B) surface mount capacitor. Three commonly attached shielding electrodes surround the A/B electrodes, and they connect to two opposing side terminations (G1 and G2) of the capacitor body. This forms a four-terminal integrated passive device (IPD) as shown. The electrode shields contain the electrostatic fields, and they suppress the energy parasitics normally transmitted from the A/B electrodes.

Together with their shield electrodes, the A/B electrodes create a pair of symmetrically balanced Y capacitors that act like two standard MLCCs connected to ground. The same two electrodes also form an 'X capacitor' across the shared center electrode. In this new design-in, each Y capacitor has capacitance C, with X being C/2. As with standard capacitors, repeating the core structure increases the capacitance.

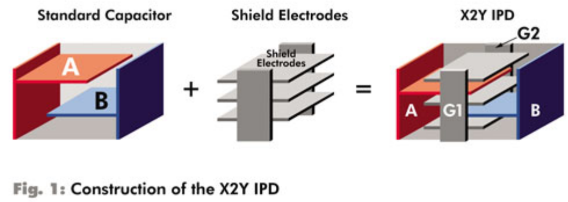

Figure 1. Construction of Phycomp/Yageo's X2Y IPD capacitor. (click image to enlarge)

Decoupling Broadband Circuits

Improvements in decoupling have largely been driven by power supplies for high-speed microprocessors, with CMOS power systems becoming particularly difficult to design[1]. One conventional approach identifies target impedance across a broad frequency range and specifies components to meet that impedance. The required value is falling rapidly (5Ù each computer generation) and is now down to sub-mÙ levels.

In designs up to approximately 1 kHz, the low impedance is provided by a system's voltage regulator and at higher frequencies by successively lower-valued capacitors such as bulk capacitors up to 1 MHz, ceramic up to 1 GHz, and above that by low value capacitors and power planes. Since circuit designers are continuously tightening layout and component specifications to reduce the target impedance across the complete frequency range[2], the possibility of designing more efficiently and reducing cost is important.

For a single capacitor, at frequencies above SRF (self resonant frequency), the Xl (inductive) term has the largest contribution to impedance, and it is determined by the ESL (equivalent series inductance). Capacitors need to be close to SRF for low impedance, with low capacitance values for decoupling at high frequency. Given a certain component size, decreasing the capacitance value raises the SRF. This approach cuts impedances at higher frequencies, and it reduces the decoupling bandwidth. Decreasing the capacitor's inductance is more effective, increasing the SRF and the effective frequency range.

Signal Line Filtering

Two MLCCs can act as shunt capacitors to give a low-impedance noise path for high-speed signal filters, with a third MLCC between the two lines filtering differential noise. A single X2Y® replaces all three MLCCs.

Feed-through capacitors[3] improve filtering by reducing parasitic inductance: two parallel paths shunt noise to ground. However, the signal current flows through the capacitor itself: traces, terminations and electrodes all add DC resistance to cause signal loss. The feed-through capacitor also has larger parasitic inductance.

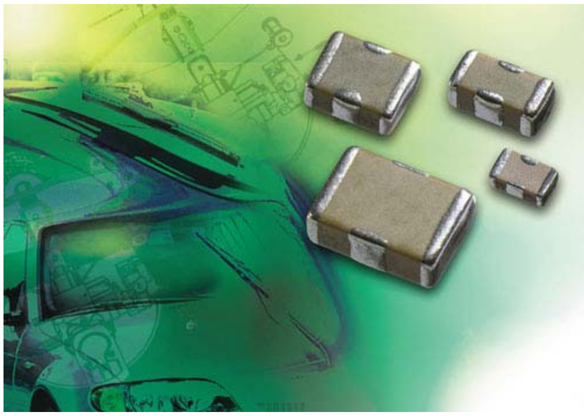

Figure 2. Yageo/Phycomp's X2Y IPD capacitor. (click image to enlarge)

Conclusion

A/B electrodes have a remarkable dual function. Together they form the single X electrode and, with the shields, they form the two Y electrodes. This allows simultaneous operation as both a common- and differential-mode filter when connected between two opposing conductors and to ground. A lower inherent inductance improves suppression at higher frequencies, with broader bandwidth. The internal shield electrodes also provide cross-talk isolation between pins (line-to-line) for filtering connector lines[3], providing better noise filtering than conventional capacitor designs.

References

[1] 'Power Distribution System Design Methodology and Capacitor Selection for Modern CMOS Technology', Larry Smith, Raymond Anderson, Doug Forehand, Tom Pelf, Tammy Roy, *IEEE Transactions on Advanced Packaging*, Vol. 22, No. 3, August 1999.

[2] Carts Europe 2002, 'X2Y Integrated Passive Devices: A Breakthrough in High-Speed Decoupling and Broadband Filtering', Rob Derkson, Bart Bouma, Jim Muccioli, Dave Anthony.

[3] 'A Capacitor's Inductance,' G. Ewell, B. Stevenson, *Proceedings of 19th Carts USA*, 1999 pp. 186-202.

About the author

For more information, please contact Dave Ritchey at Phycomp/Yageo, 16750 Westgrove Dr., Ste. 600; Addison, TX 75001, (214) 561-2033; dave.n.ritchey@yageo.com; www.yageo.com.

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