Differential-to-common-mode conversion

Any unbalanced circuit element within an otherwise well-balanced transmission channel creates a region of partial coupling between the differential and common modes of transmission at that point. The coupling can translate part of a perfectly good differential signal into a common-mode signal, or vice versa.

Such differential-to-common-mode-conversion problems frequently arise in the design of LAN adapters. For example, assume the output winding of the transformer in Figure 1 has equal capacitances (C) connected from point A to ground and from point B to ground. If the capacitances are exactly equal (and the cable and transformer perfectly symmetrical), the differential signal on the cable forces equal but opposite currents through these two capacitances. In the product chassis, the two currents perfectly cancel. The perfect cancellation implies that no current circulates between the twisted-pair cable and the surrounding chassis. In practice, however, one capacitance is always a little larger than the other.

Assume that capacitor C2 in Figure 1 represents the small amount of physical imbalance (2 pF) between the parasitic capacitances associated with circuit nodes A and B. Calculate the current flowing through this capacitor, see where it flows, and then decide whether it causes any problems.

Using Ethernet 10BaseT for this example, the drive amplitude is approximately 2V p-p on each wire, at a switching time of 25 nsec. The current forced through capacitor C2 is:

\[ i(t)_{\text{peak}} = \frac{dv}{dt} = (2 \text{ pF}) \frac{2 \text{V}}{25 \text{ nSEC}} = 160 \mu\text{A}. \]

This current flows through capacitor C2 to the product chassis. It couples from the product chassis to the earth (either through the green-wire ground or through the capacitance between the product chassis and the earth). From the earth it couples capacitively to the cabling, along which it travels as a common-mode signal riding on the twisted-pair cable back to the transformer, completing the loop.

A balanced load comprising equal-valued capacitors from A to ground and from B to ground does not generate any common-mode currents, because the currents through the two capacitors cancel, leaving nothing to exit the system in common-mode format. In this example, it is the imbalance in capacitive loading that generates the common-mode current.

A capacitive imbalance even as small as 2 pF causes a big problem in this example, because the existence of 160 μA of high-frequency common-mode current on an exposed cable easily violates US- and international-emissions regulations.