Emissions killers trap common-mode currents

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An unshielded twisted-pair cable that is transformer-coupled to a digital system can easily act as a radiating antenna, not because of the differential analog signal the cable carries, but because of common-mode currents induced by unwanted stray coupling from the digital portions of the system. These currents from fast digital transitions contain harmonics in the hundreds of megahertz and can be a nightmare to design engineers who have to make systems conform to radiated-emissions limits.

If the coupling transformer has a center tap on the winding to which the cable attaches, you can use this tap to reduce the level of these nasty common-mode currents on the cable. Connecting the tap to a quiet earth ground provides a path to shunt these currents harmlessly to earth before they can sneak out the cable and radiate (Figure 1). A capacitor in the connection provides the same RF grounding function but presents a high impedance to any 60-Hz ground loop currents if the far end of the cable also connects to a ground-referenced transformer winding. This capacitor should be only a few hundred picofarads, must have short leads and circuit traces between transformer tap and good earth ground, and must have a sufficiently high voltage rating to withstand high-voltage transients as the end market requires.

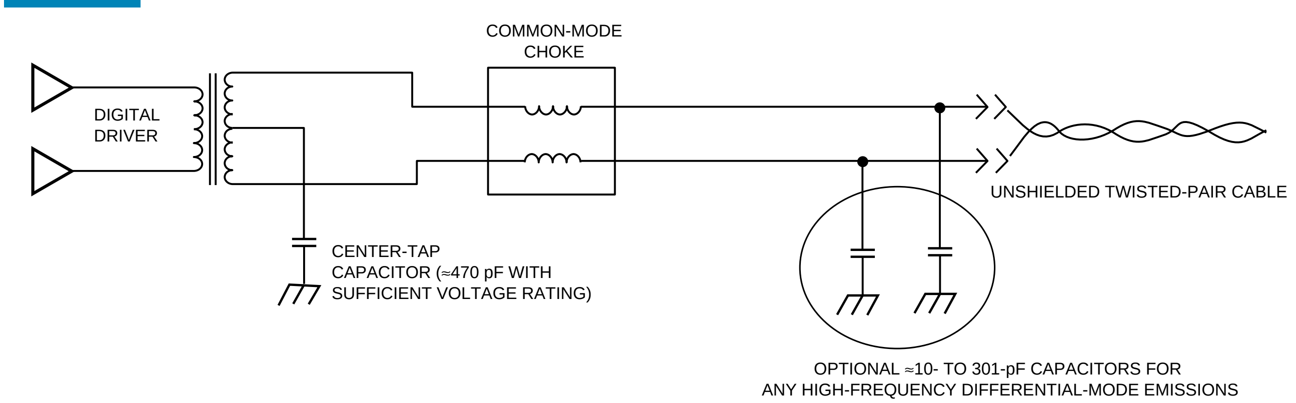
The technique works as follows: The opposite ends of the transformer winding are balanced with respect to ground; that is, the windings push and pull with equal amplitude but opposite polarity on each and every transmitted data symbol. The center of the transformer is the pivot on which the winding balances. As such, this pivot point is neutral relative to ground; an actual connection to ground makes no difference to the differential information signal.

If a common-mode signal impresses both conductors, the resulting currents at opposite ends of the winding flow both toward and away from the center tap in the same phase. This flow causes magnetic cancellation between the two halves of the winding, and the resulting inductance is very low, resulting only in the residual leakage inductance. In this way, both conductors have a low-impedance path to earth ground without affecting the wanted differential signal. Note that filtering each conductor with an RC network also provides the low-impedance path to ground; unfortunately, this filter also destroys the differential signal in high-bit-rate applications.

The technique in Figure 1 also helps reduce susceptibility to common-mode currents that external fields induce; the unwanted currents pass harmlessly through each half of the transformer winding and cancel each other out. Interwinding capacitance the usual mechanism by which common-mode voltages can affect transformer-coupled receiver inputs is less critical because both conductors have a low-impedance path to ground, resulting in minimum common-mode voltage on each conductor.

Using a common-mode choke in addition to the center-tap trap results in a real common-mode killer. The two techniques complement each other, and it can be helpful to use both together in stubborn cases. As Figure 1 indicates, you can place the common-mode choke virtually a transformer on its side in line with the cable, preferably at a point just before the cable exits the (ideally) shielded enclosure to avoid stray-noise pickup on the cable after the choke. A similar but opposite mag-

FIGURE 1



A center-tap capacitor connected to earth ground implements a common-mode current trap and reduces RF emissions. A common-mode choke in addition to this center-tap trap results in a common-mode killer.

netic magic takes place in the common-mode choke, which must present a high series impedance instead of a low shunt impedance to common-mode currents. The winding turns ratio is 1-to-1, and the polarity is such that the magnetic fields from the differential signal now cancel, resulting in almost zero attenuation other than that resulting from the leakage inductance. On the other hand, the common-mode currents cause magnetic addition, which results in high impedance and reduces the level of unwanted currents.

You can also make a common-mode choke by slipping a large ferrite sleeve over the two conductors of the twisted pairs or by winding one or more turns of the twisted pairs through a large toroid doughnut. Many ferrite suppliers make these sleeves and toroids just for this purpose. Also, well-balanced common-mode chokes of the more conventional transformer-like construction are also readily available from datacomm-transformer suppliers.

Two capacitors following the common-mode choke can reduce high-frequency differential-mode emissions caused by non-common-mode currents. (DI #2160)

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