Special Cases

Design for Compliance

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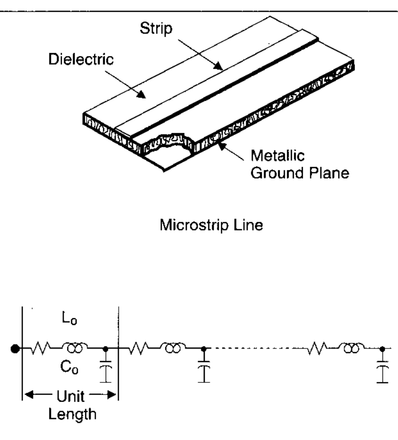
EMC techniques can be useful in certain design situations. Some problems require that attention be paid to radio-frequency issues for the design to function properly, while for others the use of high-frequency techniques is a compliance issue. The following are three good examples.

PCB Traces and Logic Reliability

With today's increasingly fast logic, PC-board transmission-line effects can be a limiting factor in a circuit's operation. A PC trace over a ground plane forms a microstrip transmission line. If it is not properly matched, the transmission line can cause switching and other overshoots that can severely compromise switching operation. Transmission-line effects must be considered when the round-trip propagation delay over the connection is of the order of the switching-circuit transition time. This situation can occur with surprisingly short connection lengths.

For example, a typical PC trace might have a propagation of 150 picoseconds (pS) per inch, or a round-trip delay of 300 pS per inch. For a device with a switching time of 3 nS, it would seem that transmission-line effects could be important at lead lengths of 10 inches or more, but in fact, the problem is usually worse. If the transmission is loaded—as when a clock or strobe line drives multiple integrated circuits—the distributed capacitance decreases dramatically, shortening the critical connection length. At several pF per IC, such loading could increase the capacitance by a factor of 5 and thus increase propagation delays several-fold (they are proportional to the square root of the capacitance per unit length). For the 3 nS part noted above, transmission-line effects could become important for lead lengths of no more than a few inches.



Characteristic Impedance: $Z_o = \sqrt{(L_o/L_o)}$ ohms
Typical Values: $L_o = 10 - 20$ nH/in
$C_o = Z_{pf}/in$
$Z_o = 70\Omega$
Propagation Delay: $T_o = \sqrt{L_o C_o}$ secs/unit length

FIGURE 1: A PC trace above a ground plane forms a microstrip transmission line.

When transmission-line effects are relevant, the impedance terminating the transmission line must be considered. A signal traveling down a transmission line will be absorbed at the far end if and only if the line is terminated in its characteristic impedance. If that is not the case, most of the signal will be reflected back in the opposite direction with the opposite polarity. If a transmission line is improperly terminated on both ends, multiple reflections will occur, resulting in a lengthened signal settling time due to multiple overshoots and undershoots.

Matched terminations control transmission-line reflections. The lines may be matched at the sending end, at the receiving end, or at both. Both resistive and R-C terminations may be employed. One particularly simple method is to match the transmission line at the originating end only with a series resistance while leaving the far end unterminated. The impedance of a CMOS IC (or, for that matter, most ICs except ECL) is very high compared with the characteristic impedances of the PC trace microstrip line. The input impedance of a CMOS circuit looks like a modest capacitance, while most bipolar logic looks like a capacitor paralleled by a resistance that is much higher than the microstrip characteristic impedance. Thus, the line acts as if it is terminated at the driving end and unterminated at the load. If it is matched at the input end, the reflected wave at the far end is reflected back to the originating end and absorbed. No further reflection occurs because of the matching source resistor. Instead of a cycle of reflections, the signal is stabilized after one round trip.

This method has the advantage of simplicity. In addition, the damping resistor can be varied when necessary to provide the best match to loaded as well as unloaded lines. Unlike termination methods that use resistive connections to Vcc and ground, it does not affect steady-state power dissipation or noise margin. The series resistor also limits peak currents, and therefore the amount of ground bounce that occurs within the driving IC.

A good discussion of these topics may be found in "High Speed CMOS Logic Design Guide" by S. Kodical, available from Integrated Device Technology.

High-Speed Video Monitors

Radiated emissions from video monitors have become a real problem. These emissions, appearing as distinctly modulated signals at harmonics of the video repetition rate, are primarily caused by the video driver of the CRT gun. Figure 1 shows one form this driver may take. A cascade circuit is used, and a common emitter stage feeds a grounded base stage. Fast rise times on the order of nanoseconds can be achieved by such an arrangement. An alternating display of black and white pixels produces a square wave at the video clock frequency, which for high-resolution monitors approaches 100 MHz, dissipating power of 10 watts or more. Keeping this signal from radiating is a major challenge. Procedures that produce repetitive characters such as those employed by the FCC aggravate the compliance problem, and units employing alternate dots to provide background shading yield worst-case radiated-emissions levels.

Where the monitor and the video driver are mounted in separate cabinets, shielded cases and a shielded coaxial run will generally be required. Note that the monitor must

Logic Family	Maximum Unloaded Signal Line Length* (in inches)
LS	25
S, AS	11
F, ACT	8
ECL	6
FCT, FCT-A	5
* Calculated on assumption of 150 pS/in propagation delay	

FIGURE 2: Transmission-line effects become important when the time it takes the line to stabilize is of the order of the logic transmission line. For faster logic families, reflections can be a problem for surprisingly short PC traces.

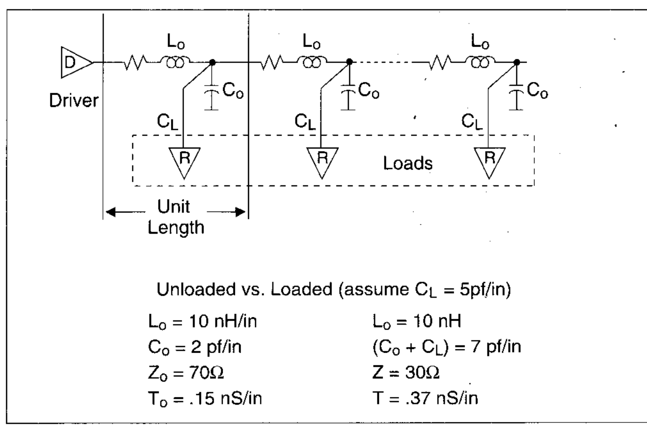


FIGURE 3: A distributed load on a transmission line raises propagation delays markedly, making signal reflections more important than ever on short runs.

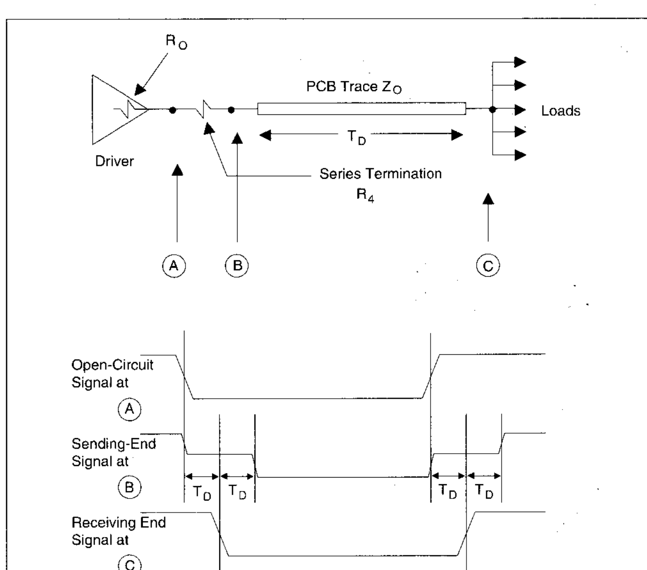


FIGURE 4: With series termination at the driving end, the logic signal stabilizes after one round trip. A single reflection occurs at the unterminated end and is absorbed by the driving resistor.

be in a shielded case for this technique to work. If the driver and the cable are shielded, but the monitor is not, the RF signal merely passes down the coaxial transmission line and radiates out the unshielded monitor, much like water spraying from the end of a garden hose. A Faraday cage must be complete to provide shielding.

Where the display unit is some distance from the monitor, ground loops and ground splitting can become a problem. Here, triaxial cable may be useful. The inner shield serves as a floated signal ground, while the outer shield is bonded to the chassis.

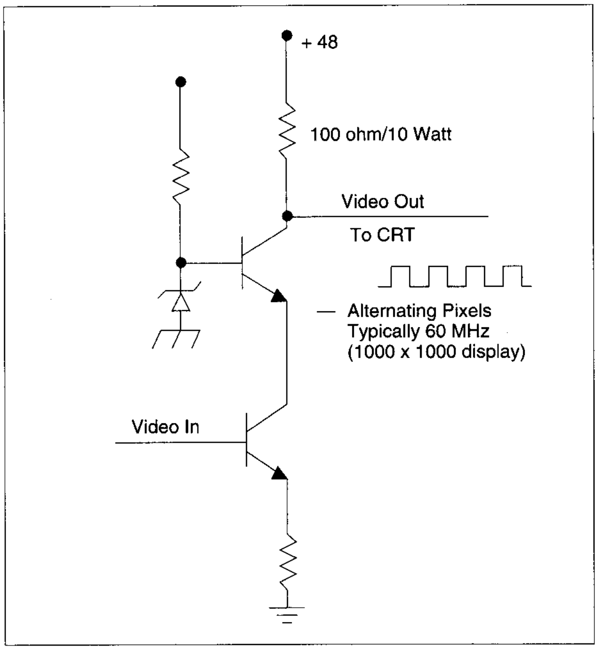


FIGURE 5: For high-resolution video monitors, the driver to the CRT gun is often of the cascade type shown here. A grounded emitter stage feeds a grounded base stage, yielding rise times of less

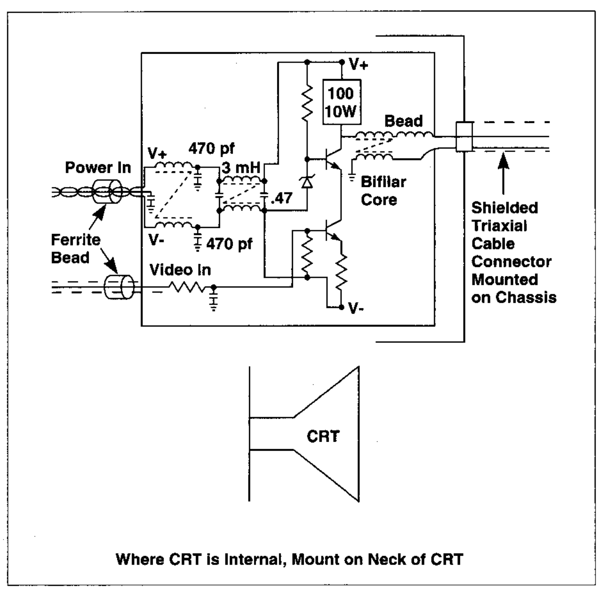


FIGURE 6: The design of a video driver is critical. In one implementation, a driver board drives a remote CRT. A twisted-lead power input feeds the board after passing through a ferrite sleeve. It is filtered and provides power to the cascade. The output passes through a bifilar choke to remove common-mode noise, and a single bead controls rise time. Signal ground on this board will be "hot," so a triaxial shielded cable is recommended. Mount the outer shield to the chassis and inner shield to signal ground; if the CRT and driver are in the same box, the driver board should be mounted directly on the CRT.

Magnetic-Field Problems

Low-frequency magnetic fields from the monitor yoke can be difficult to suppress. German VDE standards limit the emitted magnetic field to 10 kHz, and although these standards will be superseded under the EMC Directive by CISPR 22, there is reason to believe that it will continue to be necessary to control magnetic fields. Even where interference to communications is not an issue, increased public concern over the possible biological effects of low-frequency magnetic-field exposure will likely result in new requirements to contain magnetic fields.

Shielding is one approach to containment. A partial shield (necessarily open in the front) can be effective if properly designed. Since the fields to be contained are primarily magnetic, the shielding mechanism will be absorption, requiring the shield material to have a thickness of several skin depths. Skin depth is given by the formula

$$\delta = \left[\frac{2}{\omega\,\mu\,\sigma}\right]^{0.5} \quad \text{where } \omega = \text{freq.},\ \mu = \text{perm, and } \sigma = \text{cord}$$

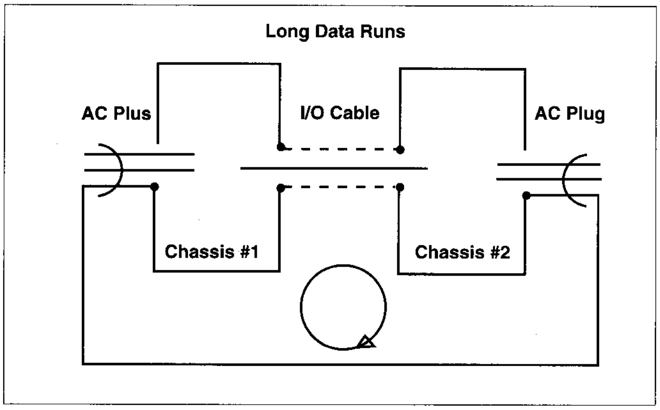


FIGURE 7: Shielded RF data runs can combine with safety grounds to produce ground loops.

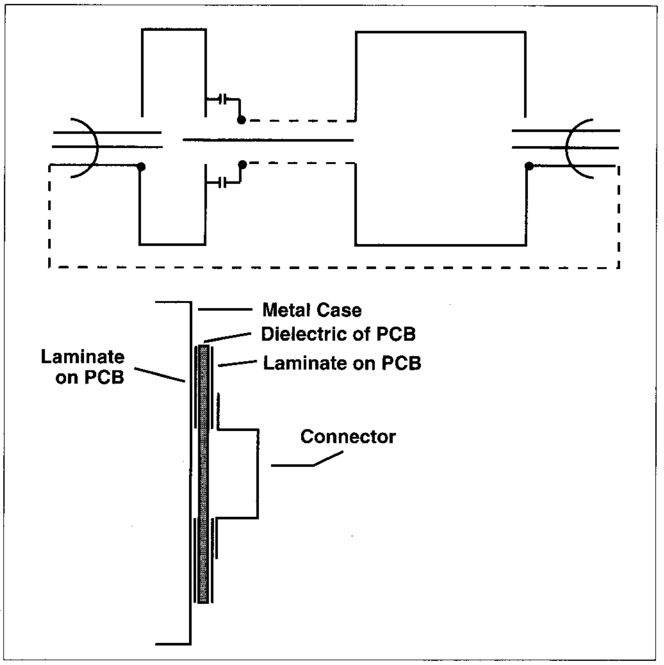


FIGURE 8: The ground loop can be broken by the use of a specially designed RF capacitor, as shown. Its capacitance (approximately 470 pf) effectively eliminates the loop for 60 Hz and lighting effects but preserves an RF ground to ensure good shielding. A PC board is used to form the low-inductance cap.

Different techniques can be used depending on the frequencies of concern. To suppress 60 Hz fields, you can try a thin, highly permeable material. Note, however, that this is not a universal solution. It will not automatically work at horizontal sweep frequencies, for example, because the permeability of most magnetic materials falls off sharply with frequency. At 15 kHz, a simple aluminum shield, with unity permeability, will do the job if it is 25 to 50 mils thick. However, a very thin sheet of mu metal probably would not work.

If some control is retained over the monitor's construction, other design alternatives may be entertained. Ideally, the yoke coil can be designed for minimum external field generation. Another possibility is the use of a field cancellation coil, which will result in both lower field levels and a more rapid rate of decrease with distance. If the problem originates in the power supply, physical redesign of the transformer (e.g., with a closed toroidal core) may alleviate the problem.

Long Data Runs

As alluded to above, long data runs can cause problems with ground splitting and ground loops. Ground splitting results when two devices are grounded to remote portions of a building's frame. If a lightning strike hits, potentials at one point on the building will differ from those at a remote point, setting up a possibly destructive potential across the grounds. Widely separated grounds can also introduce a problem at the power-line frequency. Such areas will often be served by different power transformers, and there will be differences of several volts between the two local grounds. A direct connection will connect these grounds together and can cause excessive current to flow, possibly damaging the signal cable and creating a safety hazard.

Ground loops are present where devices are grounded together and also grounded to the building's safety (third-wire) ground. Any magnetic fields within the loop will set up currents that can interfere with equipment operation.

The grounding of equipment through its third wire or by other means is generally required by the National Electric Code for designs in metal housings. At the same time, shields must be tied to the chassis to reduce RF. How, then, can both requirements be complied with? One answer lies in the use of a low-value (470 pf) capacitance ground on the data cable. This yields an RF ground without introducing a low-frequency loop. (Note that lightning transients are relatively slow, under 1 MHz.) One implementation of this scheme is shown in Figure 8.