BY HOWARD JOHNSON, PhD

Lossless propagation

Inject a fast rising edge into a long, uniform transmission structure. Imagine the signal propagating with uniform velocity and negligible attenuation for some distance.

Figure 1 depicts two snapshots taken at times t_1 and t_2. Each snapshot shows the voltages on the transmission line at that moment. At time t_1, the midpoint of the rising edge has just reached point x_1. At time t_2, it reaches the further point, x_2.

I drew an L-C ladder model to represent the transmission line. The model incorporates both parasitic capacitance and inductance. As long as the rising edge spans several sections of the model, and it does in this example, the L-C model accurately represents the behavior of a typical PCB (printed-circuit-board) transmission line from a digital application.

Look at the difference between the voltage waveforms at times t_1 and t_2. As the rising wavefront moves between points x_1 and x_2, it charges the parasitic capacitors in the diagram from a ground state (no voltage) to a voltage of V_{CC}.

Between times t_1 and t_2, enough electrical charge must enter the circuit to change the voltage on those capacitors from ground to V_{CC}. In this example, the charge emanates from the driver. It's the only source of power in the circuit.

If you believe in lossless propagation—that is, if you believe the rising edge propagates without sensible degradation, at a constant velocity, without significant loss of amplitude—then you must also recognize that in each similar unit of time, the rising-edge waveform charges a uniform amount of capacitance. In other words, during every unit of time, the circuit requires a uniform deposit of charge. A steady flow of charge into the circuit means that the driver must supply a constant current.

This simple argument ties together a number of important facts—namely, that uniform propagation of a constant step edge *requires* a constant flow of current from the driver.

Therefore, in the short term, *the input impedance of a uniform, lossless, distortionless transmission line appears purely resistive*. No other circuit but a resistor demands a constant current in response to a step change in voltage. If the circuit requires a uniform current, it looks like a resistor.

The properties of lossless propagation and resistive input impedance are inextricably linked. You can't make a lossless-propagation medium without it also having a purely resistive input impedance (in the short term).

Now, after your rising-edge signal strikes the endpoint, reflects, and returns to the source, something different happens. Propagation no longer remains uniform in that case. The input impedance of the structure may no longer appear purely resistive. That's a different story.

For any short-term event—anything to do with rise time, crosstalk, ground bounce, or other signals so short that they haven't time to get to the end of the line and return before the whole event is over—the input impedance of a PCB transmission line appears purely resistive. **EDN**

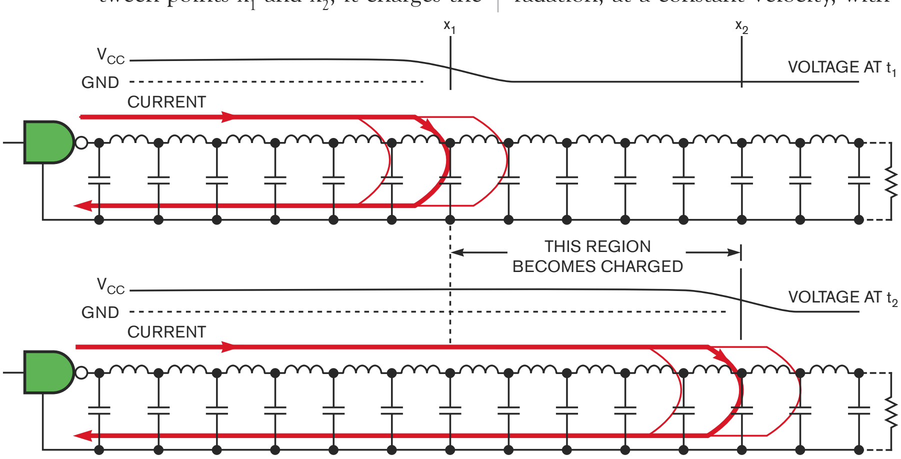

Figure 1 A steady stream of current from the driver propagates a lossless step edge.

Howard Johnson, PhD, of Signal Consulting, frequently conducts technical workshops for digital engineers at Oxford University and other sites worldwide. Visit his Web site at www.sigcon.com or e-mail him at howie03@sigcon.com.