BY HOWARD JOHNSON, PhD

Two-way street

Suppose that I gave you a highway-traffic monitor that reports total traffic density on a section of roadway but does not provide separate figures for eastbound and westbound traffic. Obviously, this sensor reveals only part of the total traffic picture. Transmission lines, like streets, support traffic in two directions. A voltage probe connected to a transmission line acts much like a traffic-density sensor. It shows an aggregate-voltage waveform but doesn't say *which way the waveform is moving*.

For example, **Figure 1** shows the composite voltage (pink) at capacitor C_3 (**Reference 1**). The waveform shows a 200-psec step followed by a negative bump at B. To decipher the cause of that bump, include in your schematic a virtual (nonphysical) 0Ω resistor, R_0. Set all the parasitics associated with that component to their minimum values.

Transmission lines, like streets, support traffic in two directions.

Export from your simulator both the voltage, v_0, at R_0 and the current, i_0, flowing through R_0. Then, use the equations in **Figure 1** to compute both forward- and reverse-moving waveforms, v_F and v_R, respectively. The composite waveform at C_3 is the sum of these two waveforms. The forward waveform (blue) appears ideal. The negative bump appears only in the reverse waveform (purple). Therefore, the bump must be a reflection coming from something to the right of C_3.

Next, consider the shape and timing of the reflected bump. The bump duration is comparable with the signal rise time, so you may conjecture that it comes from one localized spot. The center of the bump occurs 400 psec after the midpoint of the initial rising edge. That 400-psec number is a round-trip reflection delay, so the imperfection you seek must be 200 psec downstream from R_0. The only significant imperfection near that location is the receiver-load capacitance, C_4. If you remove C_4 from the circuit, the bump disappears, confirming C_4 as the source of the bump. A thorough examination of v_R reveals a second negative bump, smaller than the first, coincident with the main signal edge. That reflection comes from the C_3.

If this technique seems new or unusual to you, think back to when you were a little kid. Didn't your mother tell you to look both ways? EDN

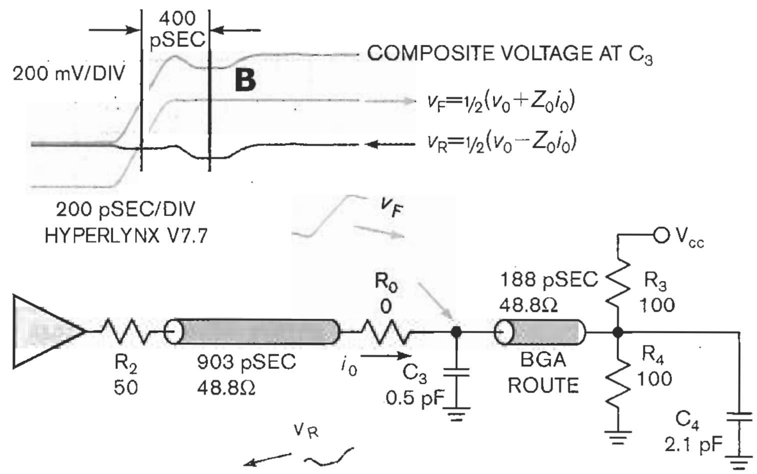

Figure 1 Voltage waveforms v_F and v_R propagate in opposite directions.

REFERENCE

1. Johnson, Howard, PhD, "Eye of the probe," *EDN*, Dec 1, 2006, pg 30, www.edn.com/article/CA6395495.

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