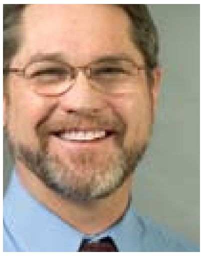

BY HOWARD JOHNSON, PhD

Z_{MIN}, a very special value

The driver in **Figure 1** precisely meets its specified high- and low-output-voltage levels with a termination resistance of 25Ω. If you increase the resistor's value, the circuit becomes progressively easier to drive, making the waveform exceed the specs in both directions. If you decrease it, the driver fails to produce a sufficiently large signal.

Resistor R_T controls the gain of the circuit, and the termination voltage controls the dc offset. Between gain and offset, you have everything you need to effect complete control over the output waveform, within reason.

When you design an end-terminating circuit, you must select an effective termination resistance large enough to guarantee that the driver can produce a full-sized output swing and then set the effective termination voltage to center the waveform so it crosses both the high- and the low-output voltages. No matter what topology you use to implement the final circuit, whether it looks like a resistor-and-battery arrangement or a voltage-divider (split-terminator) structure, the gain and offset constraints apply.

The smallest value termination resistance for which the output swing can, with a perfect setting of termination voltage, just barely touch both the high- and the low-output voltages, with no tolerance for error and no margin, is a very special value I call Z_{MIN} (minimum impedance). Understanding this value is the secret to successful end-termination design.

The value of the minimum termination impedance derives from a general output-current relation. Simply, the driver output current always equals the voltage drop across the resistor divided by its value in ohms. If you correctly set the minimum impedance, then, when the driver pulls high to the high-output voltage, the current precisely equals the high output current:

$$I_{OH}=(V_{OH}-V_T)/Z_{MIN}, \quad (1)$$

where I_{OH} is the high output current, V_{OH} is the high output voltage, V_T is the termination voltage, and Z_{MIN} is the minimum impedance.

In the low state, you get a similar relationship:

$$I_{OL}=(V_{OL}-V_T)/Z_{MIN}. \quad (2)$$

Subtract **Equation 2** from **Equation 1**:

$$I_{OH}-I_{OL}=(V_{OH}-V_{OL})/Z_{MIN}. \quad (3)$$

Solving for Z_{MIN} yields the "golden" equation of end-termination design:

$$Z_{MIN}=(V_{OH}-V_{OL})/(I_{OH}-I_{OL}). \quad (4)$$

Equation 4 says that the minimum impedance equals the spread in voltage between the high-output voltage and the low-output voltage divided by the spread in current between the high-output current and the low-output current. Your driver can never successfully drive any load with a long-term impedance of less than the minimum impedance.

When working **Equation 4**, pay attention to the polarity of the currents.

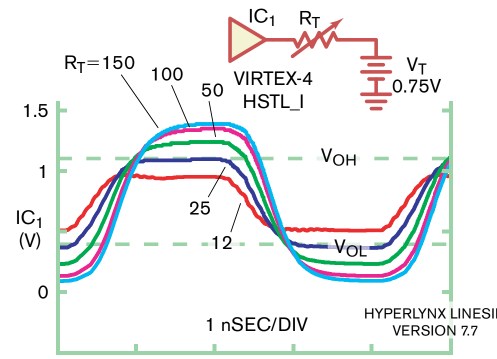

Figure 1 Reducing the value of R_T shrinks the output voltages.

Source current is positive. Sinking current is negative. For example, if a driver sources and sinks 25 mA, then its spread is (25−(−25))=50 mA.

Suppose that the minimum impedance for your driver works out to 60Ω. I would not use an end termination with that value. It leaves no room for component tolerance. Other effects, such as temperature and age variation in the termination voltage, can knock the circuit out of specification. You should use a slightly larger value, such as 70Ω.

On a 50Ω transmission line, a 70Ω termination won't be perfect. It will cause a reflection of (70−50)/(70+50)=16.7%. If that's too much for your voltage-margin budget, then consider raising the transmission-line impedance. Bring the line impedance up to perhaps 60 or 70Ω. The closer you bring the transmission-line impedance to the termination resistance, the better your system will work.

The optimal value for the termination resistance is just a little higher than the minimum impedance to account for tolerances, with a transmission-line impedance as close as practical to the termination resistance. **EDN**

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