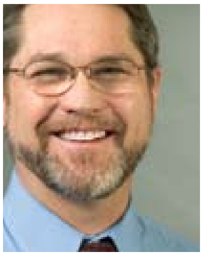


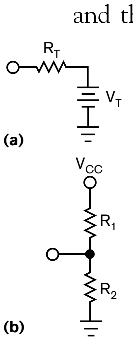
BY HOWARD JOHNSON, PhD

Designing a split termination

My last two articles dealt with the design of the end-terminating structure in **Figure 1a** (**references 1** and **2**). That structure terminates a transmission line with a single resistor value, R_T (termination resistance), leading to a fixed V_T (terminating voltage). In most cases, the termination resistance equals the characteristic impedance of the transmission line or can be a little higher than that impedance if the driver is weak. The ideal terminating voltage centers the digital waveform, producing equal voltage margins above and below the required switching levels, V_{OH} (high output voltage) and V_{OL} (low output voltage). That ideal voltage equals the average of the required high- and low-output levels minus a correction term that accounts for asymmetry in the drive capability of the source:

$$V_T = \frac{V_{OH}+V_{OL}}{2} - R_T\frac{I_{OH}+I_{OL}}{2}.$$

This **equation** assumes that the I_{OH} (high-side source current) is positive and the I_{OL} (sinking current) is negative. If those two values have equal magnitudes, they sum to zero.



$$\frac{1}{\frac{1}{R_{TMIN}}-\frac{1}{R_{2MIN}}} < R_1 < \frac{1}{\frac{1}{R_{TMAX}}-\frac{1}{R_{2MA}}}$$

$$\frac{V_{CCMAX}-V_{OL}}{\frac{V_{OL}}{R_{2MAX}}-I_{OL}} < R_1 < \frac{V_{CCMIN}-V_{OH}}{\frac{V_{OH}}{R_{2MIN}}-I_{OH}}.$$

Figure 1 If R_1 meets both the termination-impedance constraints (a) and the drive-current constraints (b), then both termination circuits perform equally well.

If you have a suitable source of terminating voltage, the structure in **Figure 1a** is easy to understand and uses fewer components than the one in **Figure 1b**. On the other hand, if no suitable voltage source exists, then you have no choice: You must synthesize the Thevenin equivalent from **Figure 1b**.

Given any combination of termination resistance, termination voltage, and V_{CC} (power-supply voltage) with voltage greater than the termination voltage, the following circuit values make the circuit in **Figure 1b** perform, from the transmission line's perspective, just as well as the one in **Figure 1a**.

$$R_2 = R_T\frac{V_{CC}}{V_{CC}-V_T}; \quad R_1 = R_T\frac{V_{CC}}{V_T}.$$

If you carefully follow the **equations**, you are now almost finished with your design. Next, you will discover that, no matter what values you have just computed, those exact values are never available in your component catalog. The values in the catalog are quantized to the nearest standard value, according to the tolerance specification for each component.

If you want your circuit to perform over a range of resistor values and over a range of possible values for the power-supply voltage, check the worst-case constraints in **Figure 1**. If resistor R_1 meets these conditions, then the circuit in **Figure 1b** will work under all conditions just as well as the one in **Figure 1a**. Make sure that the minimum and maximum values take into account temperature and aging. Some fiddling with the values will be necessary; there is no straightforward design approach that always works.

If you have difficulty satisfying the constraints, try raising your target for the termination resistance and start again. Although it will not terminate the circuit as well, increasing the termination resistance opens more room for tolerance in the circuit. The tolerance requirements for R_1 and R_2 are somewhat interchangeable. A tighter tolerance for R_2 opens more room for R_1 and vice versa.

I cannot help you further with this aspect of the design. Component selection in analog circuits always involves some last-minute juggling to meet all the tolerance requirements. I can, however, point out that the circuit in **Figure 1a** helps you understand the need for two resistor values and how they work together to meet the impedance and current-drive constraints your driver imposes.EDN

REFERENCES

1 Johnson, Howard, PhD, "Yao! What a handshake!" *EDN*, Feb 7, 2008, pg 22, www.edn.com/article/CA6526821.

2 Johnson, Howard, PhD, "Z_{MIN}, a very special value," *EDN*, March 6, 2008, pg 24, www.edn.com/article/CA6535348.

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