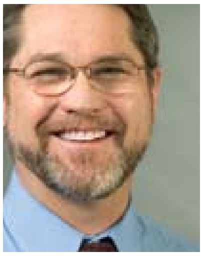

BY HOWARD JOHNSON, PhD

Yao! What a handshake!

Two men of average height meet in a crowded bar. They grasp hands. One man follows through with a vigorous up-and-down motion. The other holds on with a passive, limp action. Their meeting produces a normal, hearty shake about 32 in. above floor level. Now, suppose the second man were Yao Ming of the Houston Rockets. At 7 feet, 6 in., he ranks among the world's tallest basketball players. The same shake would occur, but slightly higher. On the other hand, if the second man were Danny DeVito, the diminutive Hollywood actor, the first must reach down to his level. A handshake accommodates the characteristics of both men.

When a logic driver meets its load, it behaves in a similar way. Begin with the driver in **Figure 1**. Connect its output to a static load. Exercise the driver by swinging its output high and low. At the driver's output, you'll see something like the waveforms in **Figure 1**.

Figure 1 illustrates a Virtex-4 HSTL-I driver. The load comprises a single resistor of 50Ω leading to an adjustable terminating voltage, V_T, all simulated with Hyperlynx. It hardly matters what type of totem-pole output you choose or how exactly you load it—all totem-pole outputs exhibit the same general behavior. You can learn a lot about drivers looking at the details of this family of curves.

Start with the terminating voltage set to 0V. This value produces the red (lowest) waveform in **Figure 1**. Driving high, IC_1 fails to attain its rated V_{OH} level. Why? At this setting, the load requires more current than the driver can provide. You can check that assumption by calculating the output current. The rule for output current is that it equals the voltage drop across R_T divided by its value in ohms.

When the red waveform rises to 0.8V, then, because the terminating voltage for that waveform is zero, the output current is $(0.8-0)/50=16$ mA. Apparently, when sourcing 16 mA, this particular driver cannot pull all the way up to V_{OH}. That's normal. Most totem-pole drivers can't pull hard enough to meet V_{OH} when loaded with 50Ω to ground. Only an exceptionally strong driver can achieve that goal.

Yao Ming is exceptionally tall and very strong. When Ming greets DeVito, the handshake pulls the actor's arm practically out of its socket.

Now go back to the chart, with V_T still at zero (red waveform). Look at the low-side output voltage. It drops to precisely 0V. *So does the current.* Whenever the output voltage equals the terminating voltage, the output current vanishes. A driver forces an output greater than V_T by sourcing current. It draws the output below V_T by sinking current. At precisely V_T, the driver does *nothing*.

Making the output voltage equal V_T is easy for a driver. The terminating voltage is a "natural resting place." If you disconnect the driver, the load immediately relaxes, all by itself, to V_T.

When Yao Ming lets go, Danny DeVito feels relieved.

Now adjust DeVito's height. Put him on a ladder. Ming needn't reach down as far, so, if DeVito is still game for testing, the handshake occurs at a higher level. In the electrical world, raising V_T always drags the output waveform higher. Lowering V_T has the opposite effect. The trick in end-termination design is setting a value of V_T high enough so the driver can pull above V_{OH} but low enough so that the driver can sink below V_{OL}—all the time not causing any shoulder injuries (in other words, not exceeding the current capabilities of the driver or burning out the terminating resistor). The driver in **Figure 1** meets those requirements with a terminating voltage of 0.75V, producing currents in the high and low states of 9 mA and −9 mA, respectively. EDN

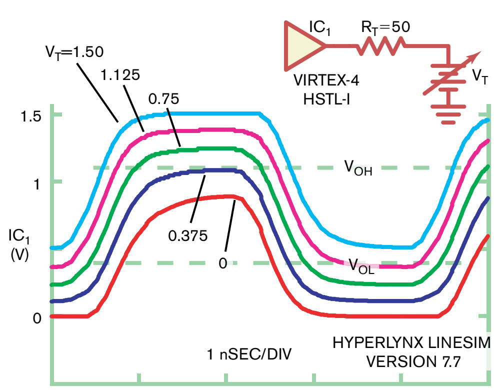

Figure 1 Raising V_T drags the output voltage higher; lowering it does the opposite.

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