Rule of Thumb #3 Signal speed on an interconnect

Eric Bogatin - December 17, 2013

Eric Bogatin, Signal Integrity Evangelist, Teledyne LeCroy, explains a rule of thumb that estimates the speed of a signal on an interconnect.

Speed ~ 6 inches/nsec = 15 cm/nsec

This rule of thumb estimates the speed of a signal on an interconnect.

Remember: before you start using rules of thumb, be sure to read the Rule of Thumb #0: Use rules of thumb wisely.

Previous Rule of Thumb: RoT #2, Bandwidth of signals from their clock frequency.

When a voltage is applied between the signal and return path of a transmission line, like when a driver turns on, there is absolutely nothing we can do to prevent the signal from propagating down the transmission line. Figure 1 is an example of a snapshot of the voltage distribution on a transmission line. It is this voltage distribution which propagates.

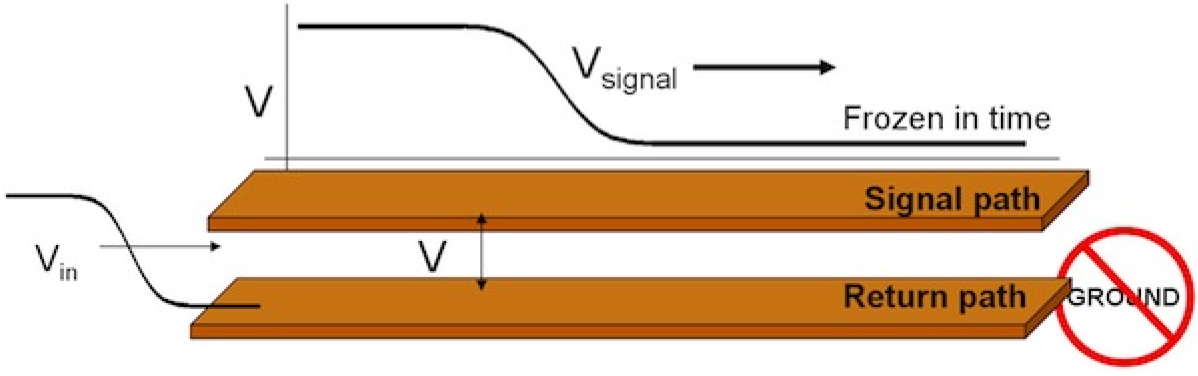

Figure 1. The propagating signal on a transmission line, frozen in time.

A signal is really a changing voltage between the signal and return conductors, and this changing voltage is really a changing electric field. Maxwell's equations describe the fundamental property of changing electric fields: that they will propagate.

Another name for a changing electric field is light. In a transmission line, the frequency components of the light are in the RF or microwave regime, rather than in the optical regime, but an RF signal is still light. It will propagate down the interconnect at the speed of light.

In air, the speed of light is about 186,000 miles/sec, or 300,000 km/sec. However, when it comes to interconnect dimensions and signal rise times, these units are about as useful as using units of furlongs per fortnight. (For those interested, the speed of light in air is 1,800,000,000,000 furlongs/fortnight).

Instead, a much more useful value for the speed of light in air is 12 inches/nsec or 30 cm/nsec.

When the electric field travels in a dielectric material, like a circuit board laminate, the speed of the light slows down with the square root of the dielectric constant, Dk. For example, in FR4, the Dk is 4, so the speed of light in most laminate materials is

$$\text{speed} = \frac{12\text{inches}/\text{nsec}}{\sqrt{\text{Dk}}} = \frac{12\text{inches}/\text{nsec}}{\sqrt{4}} = 6\text{in}/\text{nsec} = 15\text{cm}/\text{nsec}$$

Even in high-performance laminates, with a Dk of 3.5, for example, the speed of a signal is 12/sqrt(3.5)= 6.4 in/nsec, pretty close to 6 in/nsec. In the case of a coax cable with polyethylene dielectric, with Dk = 2.3, the speed is 12/sqrt(2.3) = 7.9 in/nsec, still not too far off from 6 in/nsec.

If we want to carry around one number to estimate the speed of a signal in an interconnect we should remember the rough rule of thumb:

The speed of a signal on an interconnect is 6 inches/nsec = 15 cm/nsec.

An interconnect trace on a board that is 12 inches long has a time delay of about 12 inches/6 in/nsec = 2 nsec.

The time delay through an interconnect is the length/speed. We sometimes call the delay per inch, 1/speed, the wiring delay. A comparable rule of thumb is:

The wiring delay of an interconnect is about 170 psec/inch or 70 psec/cm.

For example, if a package lead is 0.5 inch long, its time delay is 0.5 in x 170 psec/in = 85 psec.

If you are worrying about the fact that the speed of a signal on a microstrip is faster than in a stripline, don’t use this rule of thumb, find the effective Dk with a field solver and use that.

Now you try it:

1. What is the time delay for a backplane trace that is 30 inches long?

2. What is the length of the rising edge of a signal on an interconnect when the rise time is 1 nsec?

Leave your answers and your own examples in the comments section

Next rule of thumb: RoT #4: The skin depth in copper

Also See:
Analyze high-speed interconnects
Stars of DesignCon: Signal Integrity in tricked-out high-speed interconnects
Sub-microsecond interconnects for processor connectivity: the opportunity
Rule of Thumb: The bandwidth of a signal from its rise time