How to estimate ground bounce in a connector: Rule of Thumb #8

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This rule of thumb estimates the amount of ground bounce to expect in a connector or package lead.

% ground bounce noise = 2% per signal per nH / RT[nsec]

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 #7: Total inductance in the return path.

Ground bounce is the noise generated on the return path due to excessive total inductance in the return path and the dI/dt of the switching current. If this compromised return path with the higher total inductance is shared with another signal path, the other signal path will see the ground bounce noise as cross talk.

The more signals that switch simultaneously and share the same return path results in more dI/dt through the higher total inductance of the return path, and the larger the ground bounce voltage noise. Figure 1 shows an example of the measured ground bounce on one line in a bus tied low as four other lines on the bus switch.

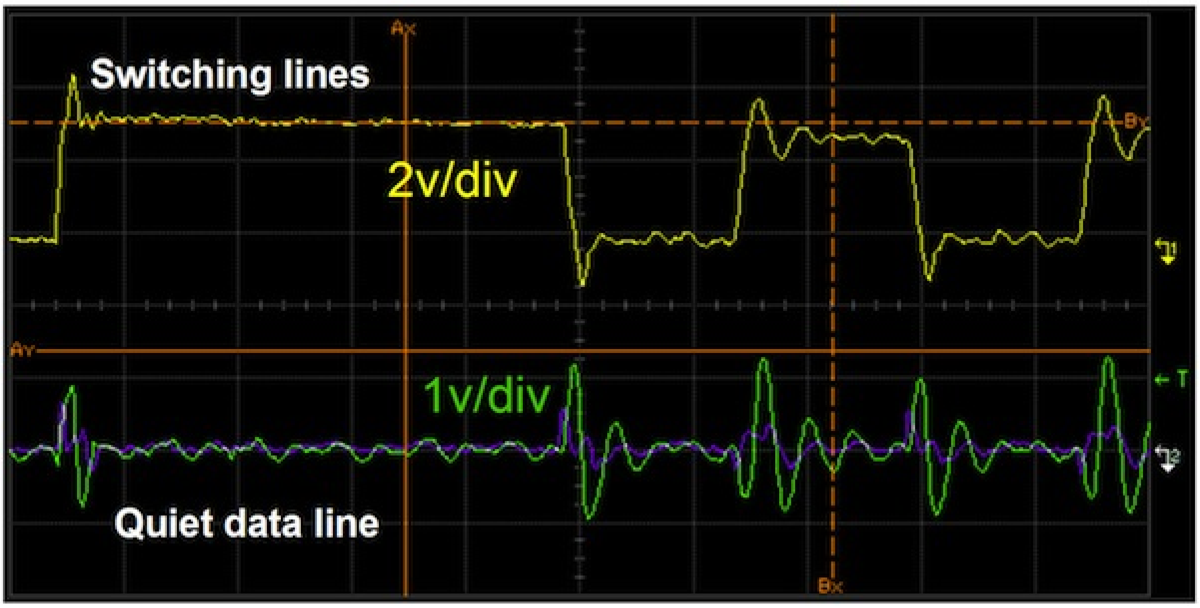

Figure 1 Example of the measured ground bounce on a quiet line.

Ground bounce can be a real problem.

Of course, it's not about "ground" it's about the return path, but when I go around saying "return path bounce" no one reacts to me. If I say "ground bounce" everyone gives a shudder of fear and then pays attention.

We can estimate the amount of ground bounce to expect if we know the inductance of the return path (see Rule of Thumb #7), the dI/dt of each signal switching, and the number of signals simultaneously switching.

The ground bounce noise generated across the total inductance of the return path is

$$V_{gndBnc} = L_{return} \frac{dI}{dt}$$

The dI/dt can be estimated from the signal level, Vsignal, the characteristic impedance of the interconnect, Z0, the number of signal switching, n, and the rise time of the signal, RT,

$$dI = n \frac{V_{signal}}{Z_0} \quad \text{and} \quad dt = RT$$

to arrive at

$$V_{gndBnc} = L_{return} \frac{dI}{dt} = L_{return} \frac{V_{signal}}{Z_0 RT} = L_{return}\, n \frac{V_{signal}}{Z_0 RT}$$

For the special case of a 50 Ohm environment, this gives a simple expression for the ground bounce noise,

$$\%noise = \frac{V_{gndBnc}}{V_{signal}} = L_{return}\, n \frac{V_{signal}}{Z_0 RT} = n \frac{L_{return}}{50\Omega\, RT} = 2\% \frac{n\, L_{return}}{RT}$$

This is the origin of the simple rule of thumb that the ground bounce noise is 2% per nH per switching signal / RT in nsec.

For example, if we have three signals switching and sharing the same return path, with 5 nH of total inductance in the return path and switching with a 2 nsec rise time, the ground bounce on the return path would be

2% x 5 x 3 / 2 = 15%

This is a bit more than most systems can tolerate but may still work. And if you go to a die shrink silicon, lower cost but shorter rise time of 1 nsec, then the ground bounce will be 30%. This is pathological and can kill most systems. Ever wonder why using one vendor's silicon may work fine, but another vendor's same chip, the product doesn't work anymore? You begin to see how easy it is to pick up excessive ground bounce.

Now you try it:

1. How much ground bounce would you expect in a connector 0.5 inches long and with 3 signals sharing the same return path, with a 1 nsec rise time?

2. How much ground bounce would you expect in a BGA package lead, 0.4 inches long and with 4 signals sharing the same return path, with a 0.5 nsec rise time?

Next rule of thumb: RoT #9: Loss in Gigabit Serial Link Channels.

See Also

- Total loop inductance per length in all 50 Ohm transmission lines in FR4: Rule of Thumb 6
- Capacitance per length of 50 Ohm transmission lines in FR4
- Skin depth of copper: Rule of Thumb 4
- Signal speed on an interconnect: Rule of Thumb 3