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On The Problem of Jitter and Skew in Gigabit and Faster Signals Caused by Laminate Weaves

In recent months much has been written about jitter and skew on Gigabit per second and faster differential signals that are traceable to the glass weave in PCB laminates. One solution that has been proposed is to route the signals in the PCB at an angle to the fibers in the glass weave to solve this problem. In fact, there is even one company that has applied for a patent on the concept of routing the signal traces at an angle to the weave of the glass fibers for this purpose. Another solution proposed is to use a random distribution of glass fibers. Once the reason for the problem is understood, there is a much simpler solution.

Figure 1. shows the glass weave of 1080 glass, a popular glass style for "high speed" PCBs, along with a 3.5 mil wire to show how signal traces compare to the glass threads in the woven cloth. As can be seen, the signal trace is quite small compared to the pitch of the threads in the weave (approximately 16 mils) and is small compared to the gaps between threads.

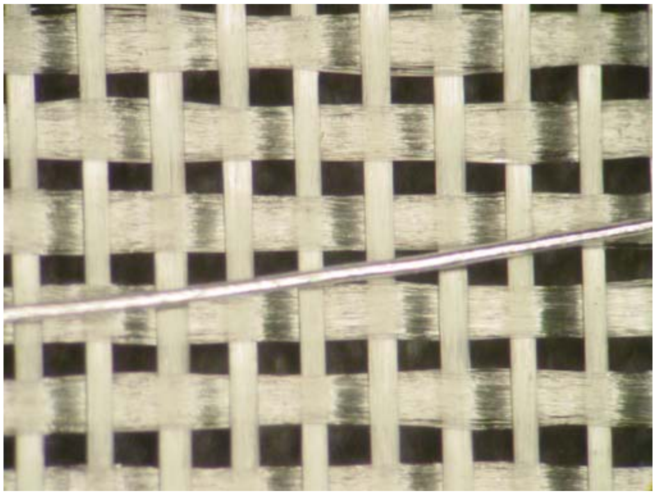

Figure 1. 1080 Glass Cloth with 3.5 Mil Wire

It is easy to see that the trace could run over a thread for some distance and then between threads for some distance. When the trace is over a thread it sees a dielectric constant of almost 6 and when it is between threads it sees a dielectric constant near 3. This results in an impedance variation that is very large. It also results in a velocity change from about 5 inches per nanosecond to about 7 inches per nanosecond, respectively. If one member of a differential pair traveles over a fiber while the other traveles between fibers their travel times would be quite different resulting in significant skew.

Figure 2. shows the impedance versus length for a 4-mil, 50 -ohm trace traveling over 1080 glass cloth.

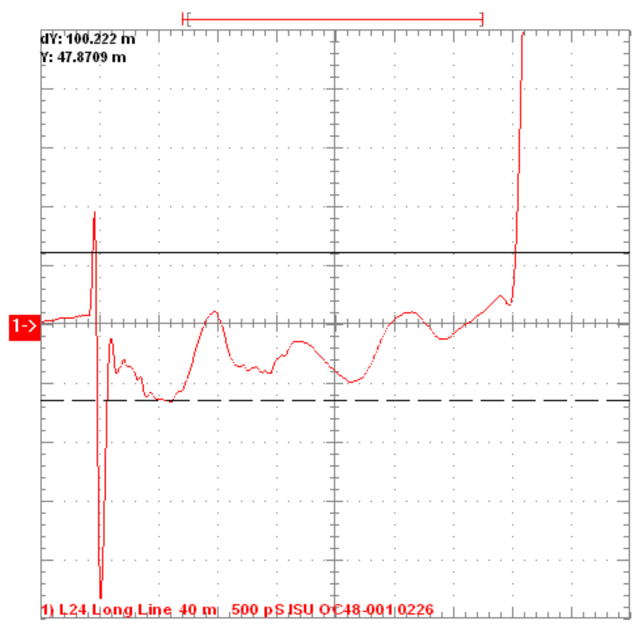

Figure 2. Impedance vs. Length Over 1080 Glass

The solid upper line and the dotted lower line are the ±10% limits around the 50-ohm centerline. Notice that the impedance has varied to minus 10% on one side and just barely gets over 50 ohms on the other side. This is a trace that remains on the same layer and has less than a 0.5 mil width variation. The variation is caused by the trace traveling on and off the glass fibers. Clearly, the velocity will vary in the same way resulting in both excessive jitter and variations in delay between two members of a differential pair.

What can be done about this problem? Routing signals at a 45° angle would solve this problem but at the cost of very difficult PCB layout or difficult lamination changes to achieve the off-angle routing of signal traces.

The problem shown above is the result of uneven distribution of glass over the surface of the laminate**.**

One way to solve the problem of uneven glass distribution would be to increase the density of threads in the weave from a pitch of 16 mils to something much tighter. The result would be a much more expensive glass cloth along with a limitation on how thick the cloth could be because of the very small threads. Perhaps there is another solution.

Figure 3. is a picture of 3313 glass cloth with the same 3.4 mil wire for comparison. The pitch of the threads is still approximately 16 mils as it is with 1080 glass. The difference is that the threads are flat, much like the webbing in a lawn chair. The result is a much more uniform distribution of glass across the surface. Notice that there are no gaps between

threads. When viewed from the side, the glass distribution is quite uniform. Figure 4. is a plot of impedance vs. length for several 50-ohm traces traveling in both X and Y directions across a piece of laminate made from 3313 glass. Notice that the impedance is quite uniform along the length of each trace.

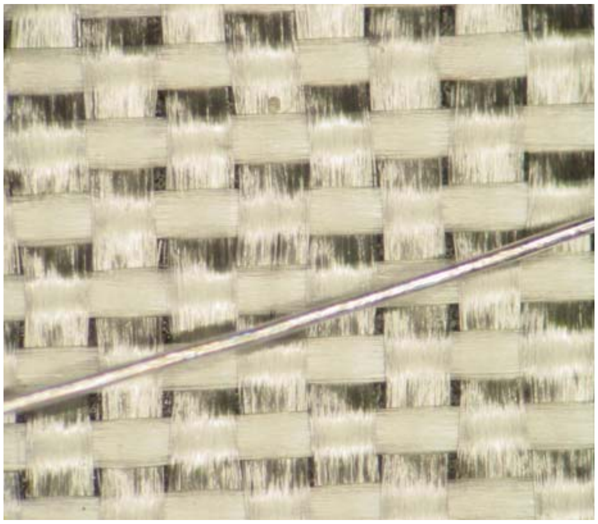

Figure 3.3313 Glass Cloth with 3.5 Mil Wire

By simply changing the style of glass used in the laminate, the problems of varying impedance and velocity have been substantially reduced. Tests have shown that the jitter and skew problems encountered with 1080 and 106 glass styles have been reduced enough using 3313 glass that 10 gigabit per second differential signaling can be done successfully with resin systems such as “Hi Tg” FR-4.

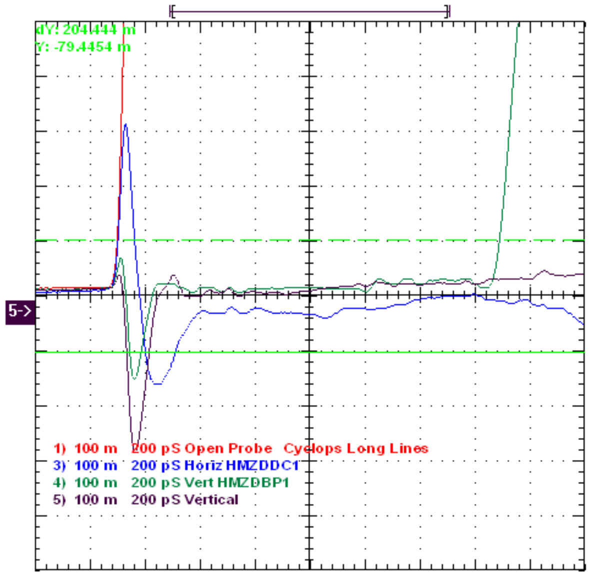

Figure 4. Impedance vs. Length Over 3313 Glass

The author has fabricated dozens of PCB containing multi-gigabit signals using this glass style with very good results. The 3313 glass style is not commonly offered by laminate suppliers, not because it is not readily available, but, rather, because it is not being requested. Perhaps it is time for laminate suppliers to add this weave as a standard offering.

All figures courtesy of John Zasio.

References:

McMorrow, Scott etal, “Impact of PCB Laminate Weave on Electrical Performance”, DesignCon, Fall 2005.

Bogatin, Eric, “Skewering Skew, Laminate Weave Induces Skew”, Printed Circuit Design, April 2005.

About the author:

Lee W. Ritchey is currently President of Speeding Edge, a leading training and consulting company specializing in the design of high speed PCBs and systems. He has a BSEE in electronic engineering from California State University in Sacramento California. He has spent his forty-year career designing high speed PCBs for supercomputers and high performance internet products. He is currently actively serving as a signal integrity and fabrication consultant to several leading computer ,workstation and internet equipment providers. He has taught his high speed design course to more than 6000 engineers and PCB designers and continues to offer these classes through his company, Speeding Edge, www.speedingedge.com.

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