Design Note:

HFDN-17.0
Rev.1; 04/08

Equalizing XAUI Backplanes with the MAX3980

maxim integrated™

Equalizing XAUI Backplanes with the MAX3980

1 Introduction

This discussion explores the performance of the MAX3980 XAUI Equalizer in compensating backplane interconnects that operate at 3.125Gbps. This includes testing in the presence of crosstalk. Although the examples in this discussion use 3.125Gbps, the MAX3980 is capable of operating in the range of 2.5Gbps to 4Gbps providing that the data is limited to a consecutive identical digit (CID) length of 7 bits. Optimum performance is achieved with 8b/10b coding (CID $\leq$ 5) as found in the IEEE802.3ae 10G Ethernet standard, clause 47. Clause 47 describes an electrical interface called the “10Gigabit Attachment Unit Interface.” This is abbreviated as XAUI. The “X” is the Roman numeral for 10. For more information about the IEEE802.3ae 10G Ethernet standard, go to http://grouper.ieee.org/groups/802/3/ae/.

2 The Problem

The primary objective of moving information between any two points is to do so with as few errors as possible. The XAUI has clearly defined the electrical characteristics of the transmitter and receiver. The transmission channel is described by an allocation of its loss budget. The XAUI states that the near end (transmission point) output deterministic jitter is 0.17UI while the far end (receive point) deterministic jitter is 0.37UI. The difference of 0.2UI (64ps) is allocated to the transmission medium. To account for the effect of crosstalk and other interference, an additional 0.1UI of receiver tolerance has been allocated. Although the feasibility of the XAUI links spanning 1 meter was given careful consideration, it was also mentioned in the XAUI document that, “The performance of an actual XAUI interconnect is highly dependent on the implementation.”

There is no doubt that many opportunities exist where compromises or caution will force designers to avoid approaching theoretic limits. The result will be a good and sound design, but with limited reach. When this reach conflicts with other objectives such as channel capacity and overall chassis size, how should such a conflict be resolved?

The key to extending the length of a dispersive transmission medium is to compensate for the inter-symbol interference (ISI) that is distorting the signal. In this case, the copper transmission line on common glass-epoxy circuit board material, such as FR4, is introducing ISI due to dielectric and skin losses. Figure 1 shows the result of transmitting a simple K28.5$\pm$ pattern through a 40-inch long, 6-mil wide transmission line of FR4. Although there is some vertical opening, the horizontal closure of 100ps is 0.31UI. This has already used the entire XAUI interconnect budget.

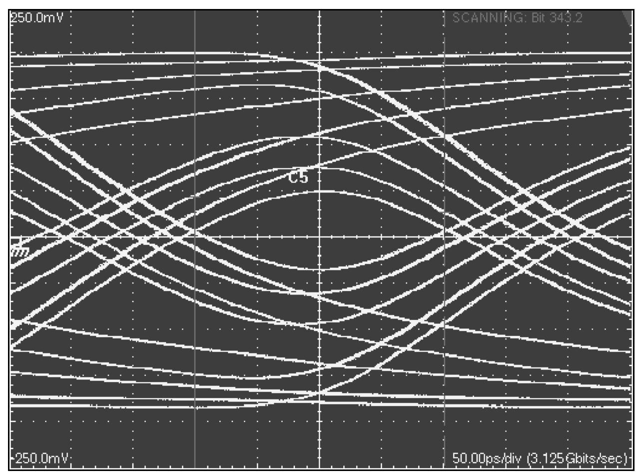

Figure 1. A simple K28.5± pattern (0011111010 1100000101) at the end of a 40in long, 6mil wide FR4 line

3 The Solution

The MAX3980 is a low-risk solution to extend the length of a XAUI interconnect. It is an adaptive equalizer that automatically compensates for dielectric and skin losses that cause inter-symbol interference (ISI).

The result is an output eye that is open both vertically and horizontally. Figure 2 shows the output of the MAX3980 when the signal of Figure 1 is applied to the input of the MAX3980. The MAX3980 has compensated for nearly all of the jitter caused by the ISI of the FR4 transmission line. It is obvious that the data fidelity has been restored.

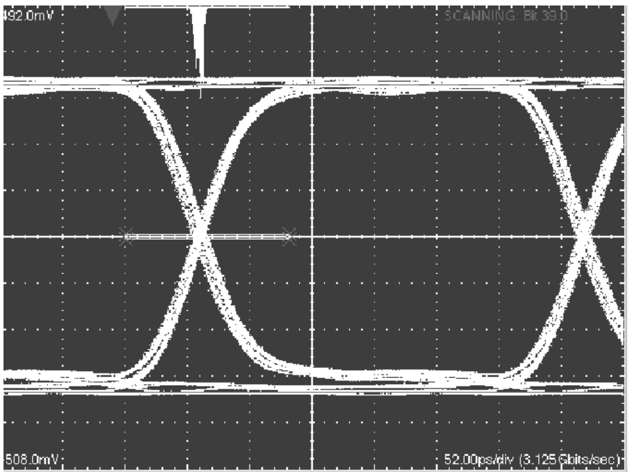

Figure 2. The output of the MAX3980 after transmitting a K28.5± character over a 40in long, 6mil wide FR4 line

This example demonstrates just how good the equalizer performs under ideal conditions. Indeed it almost completely compensates for the dispersive effect of the link. The next test is to see how the equalizer behaves in a more realistic environment.

4 Getting Real

To better assess the performance of the MAX3980, a test backplane will be used. Two different link lengths will be evaluated, each with and without the presence of interfering or offending signals. Bipolar line drivers at the output of the generators will add realism by eliminating the nearly ideal output waveform shape of the pattern generators.

4.1 Test Apparatus

Figure 3 depicts the backplane evaluation apparatus. The signal that will traverse the link will be generated by the HP BitAlyzer, shown at the right. This signal will be referred to as the "victim." The offending signals that will cause crosstalk are generated by the HP70843B, shown at the left. These signals are the "aggressors."

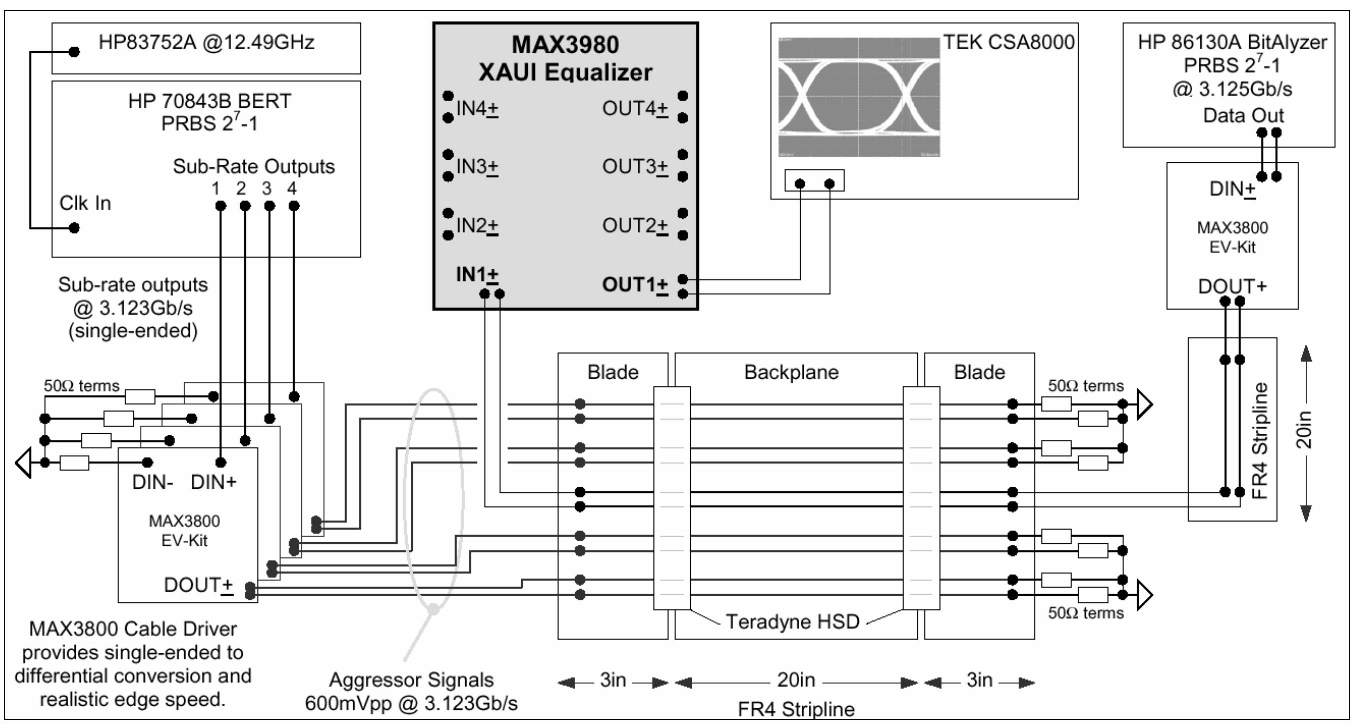

Figure 3. Backplane evaluation setup

Four aggressor signals are created by running the HP70843B generator at 12.49Gbps and using the quarter-rate outputs as the data source. The data rate of the aggressor signals is slightly different than the victim to avoid synchronization. Rather than use the clean and fast output of the pattern generators directly, all of the signals are driven by a bipolar cable/line driver (part of the MAX3800) for realism. Figure 4 shows the output of this driver. This eye pattern has approximately 30ps of deterministic jitter and the edge speed is approximately 80ps.

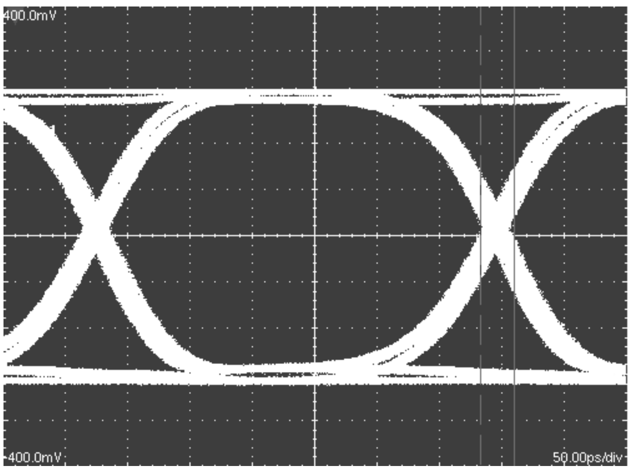

Figure 4. Input to the transmission link

In experiment 1, the transmission link is a backplane provided by Teradyne. The backplane connector is the Teradyne HSD. The backplane is 0.25in thick and uses 8mil wide, loosely edge-coupled lines that are 20in long. Each blade card adds 3in of FR4 terminated at SMA connectors, for a total of 26in.

Experiment 2 introduces additional loss with a 20in long, 6mil wide FR4 line between the signal source and the backplane.

In both experiments, more stress to the equalizer is provided by the use of a PRBS 2^7-1 pattern. With XAUI adhering to 8b/10b coding, the longest CID is 5 bits. The PRBS 2^7-1 has up to 7 consecutive ones and 6 consecutive zeros.

4.2 Experiment 1: 26in Span

This first experiment uses the apparatus of Figure 3 without the extra 20in length of FR4 between the generator and the backplane/blade assembly. Figure 5 shows the victim signal without the aggressor signals applied and after traveling the full 26in span of the two blade cards and the backplane.

The eye pattern has a vertical opening of approximately 20% and deterministic jitter of approximately 100ps (0.31UI). Figure 6 shows the restored data signal after being equalized by the MAX3980. The resulting deterministic jitter is approximately 50ps (0.16UI).

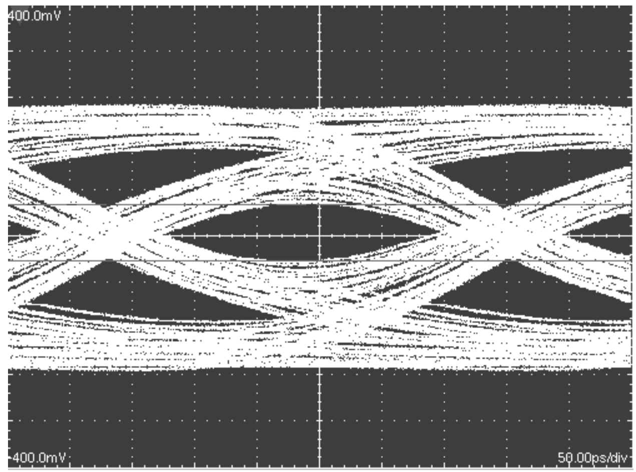

Figure 5. Output of the backplane/blade assembly (26in FR4), without crosstalk applied

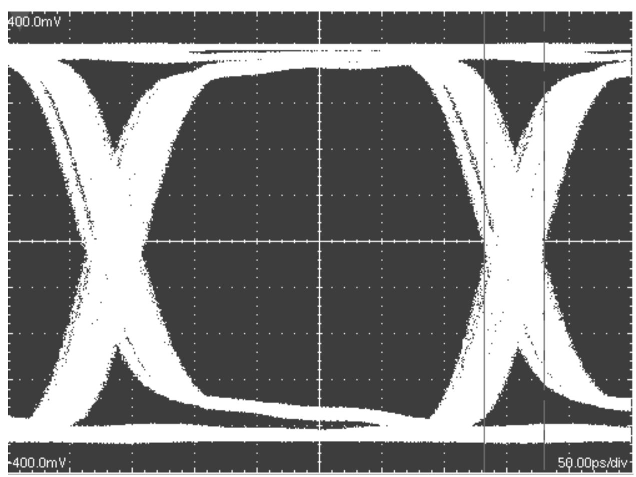

Figure 6. MAX3980 Equalizer output after two HSD connectors, 26in of FR4, without crosstalk applied

The MAX3980 allowed the backplane link to be traversed while adding only 20ps of jitter. This is well short of the 64ps (0.2UI) budgeted for the link, leaving plenty of margin to give up to crosstalk and other noise sources.

Figure 7 shows the output of the MAX3980 when the aggressor signals are applied to the backplane. The random jitter has increased but there is still plenty of margin.

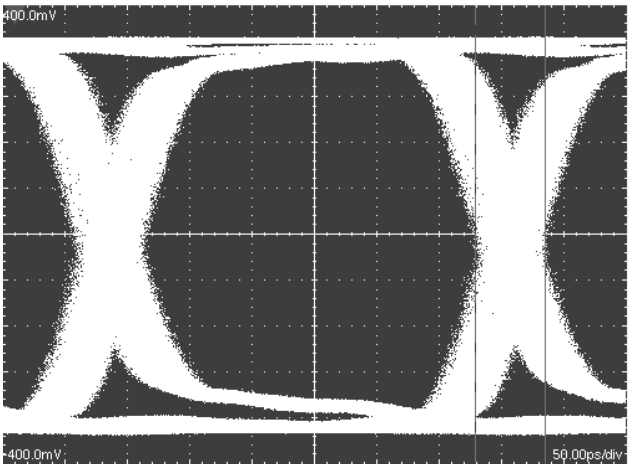

Figure 7. MAX3980 Equalizer output after two HSD connectors, 26in of FR4, with crosstalk applied

4.3 Experiment 2: 46in Span

This experiment uses the apparatus of Figure 3 including the extra 20in length of FR4 between the generator and the backplane/blade assembly. Figure 8 shows the victim signal without the aggressor signals applied and after traveling the full 46in span of the two blade cards and the backplane. The eye is completely closed! Figure 9 shows the restored data signal after being equalized by the MAX3980. The deterministic jitter is approximately 75ps. This is an increase of 45ps, but still less than the 64ps (0.2UI) budgeted for the link.

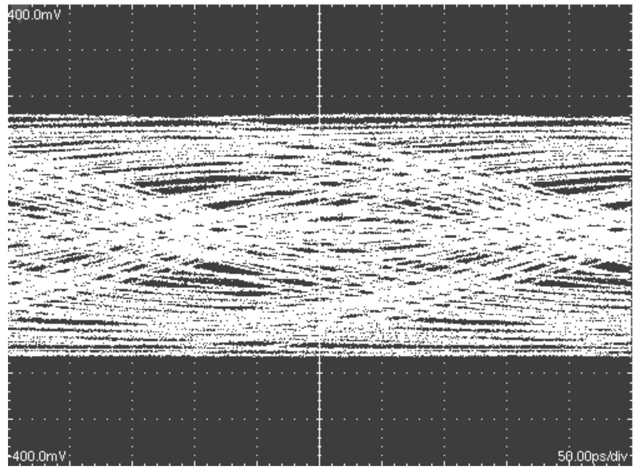

Figure 8. Output of the backplane/blade assembly (46in FR4), without crosstalk applied

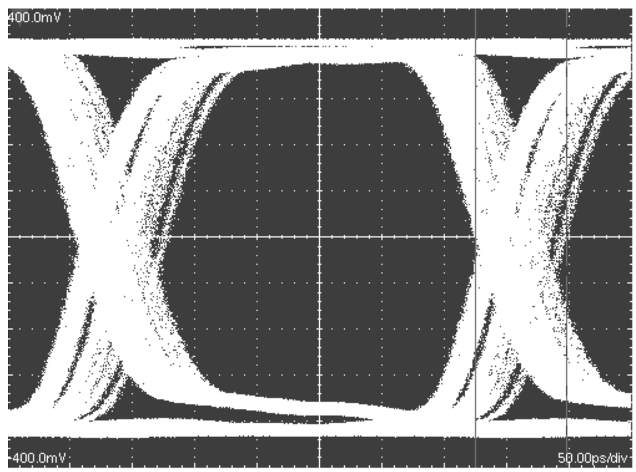

Figure 9. MAX3980 Equalizer output after two HSD connectors, 46in of FR4, without crosstalk applied

Figure 10 shows the extreme case after spanning a 46in FR4 link with two HSD backplane connectors with crosstalk from an aggressor transmission inserted at the receive side of the backplane. Although not as wide open as a typical advertising picture would show, the eye is open and well within the jitter budget.

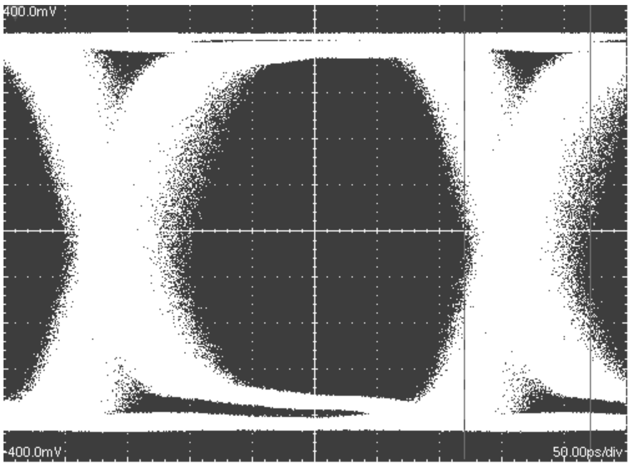

Figure 10. MAX3980 Equalizer output after two HSD connectors, 46in of FR4 and with crosstalk applied.

5 Conclusion

In this discussion the ability of the MAX3980 to extend XAUI copper links on FR4 has been demonstrated. After considering all that was thrown at it, the MAX3980 does a great job of recovering an otherwise lost signal. Giving practical consideration to the XAUI jitter allocated to the transmission medium, it is difficult to span 20in of FR4 with connectors without exceeding the XAUI budget. To enable longer spans, compensation is required. The MAX3980 is a convenient way to achieve a 40in span and exploit the meager jitter budget for maximum advantage.