**Design Note:**

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# Equalizing Gigabit Copper Cable Links with the MAX3800

## MAXIM High-Frequency/Fiber Communications Group

*Maxim Integrated Products*

# Equalizing Gigabit Copper Cable Links with the MAX3800

## 1 Introduction

Interconnecting communication systems with short-distance high-speed serial data links is a growing need. Until now, most chassis extensions or rack-to-rack connections over 20 feet relied on copper cable at rates of 1Gb/s and below. Some links are operating at 2.5Gb/s over copper, but for 10ft or less. All other links at 2.5Gb/s rely on optical transmission for distances of 50ft or more. With the introduction of the MAX3800 adaptive cable equalizer, it is possible to span 100ft at up to 3.2Gb/s with inexpensive copper cable. Although the MAX3800 was designed to compensate copper cable, it can be used to compensate circuit board transmission lines. The data presented in this design note is a brief survey of the MAX3800's performance with a few different cables and a sample of common FR4 board material.

## 2 Test Setup

Figure 1 shows the setup that was used to evaluate the performance of the MAX3800 with the various cables. In each case, the applied pattern was a PRBS-7 with an output level of 1Vp-p. The same setup was used for the FR4 material, except the output level was 0.5Vp-p. The eye diagrams were acquired using the Tektronix CSA8000. The FrameScan® feature of the CSA8000 was used to reduce random jitter so that the deterministic jitter could be measured directly.

## 3 Media

Four cable samples varying in cost from a few pennies per foot to tens of dollars per foot were evaluated. The cables from W.L. Gore are a matched set of 50Ω coax cables and serve as a laboratory reference. These are very expensive cables that have guaranteed loss characteristics (i.e., skin and dielectric). Most manufacturers do not attempt to specify loss characteristic other than a few points where the loss is not very significant. After all, most cable users are interested in the low-loss frequency range of the cable. Without detailed cable characteristics, it is difficult to predict the performance of the equalizer. The samples tested are intended to assist in selecting cables.

The 100ft-long RG179B cable is a 75Ω cable that was used to drive the MAX3800 equalizer in a singled-ended fashion. No special matching network was used to adapt between 50Ω and 75Ω environments. For such a long length of cable, any reflections are greatly attenuated by the cable and pose no problems to the equalizer.

The 100ft-long Belden 9207 is a 100Ω twin-axial cable that is 18-AWG with a heavy-duty protective casing.

The Madison 14887 is shielded twisted-pair, 100Ω cable that is very inexpensive. It is intended for use in LVDS applications. It is 30-AWG and extremely lightweight. It can be ordered in multipaired bundles, making it convenient for multichannel interconnect. Similar cables are available from Amphenol and Tensolite.

The FR4 circuit board sample is a 50Ω transmission stripline that is 50 inches long and 6 mils wide. It was driven in a single-ended fashion with 500mVp-p at the pattern generator.

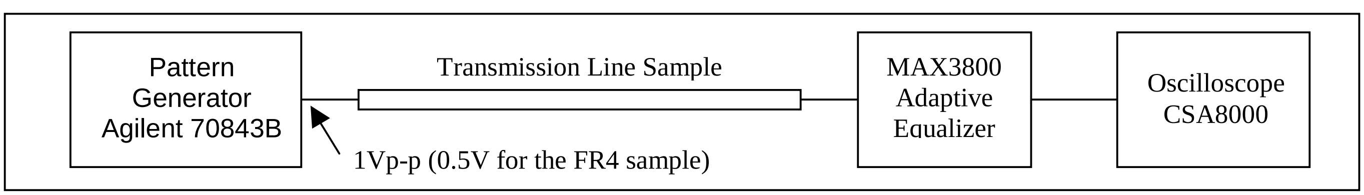


*Figure 1. Test setup. When using single-ended lines, the unused input to the MAX3800 should be AC-terminated to the same impedance as the transmission line.*

## 4 Results

Table 1 shows a summary of bit rates, lengths, and deterministic jitter for the different media samples. Figure 2 shows that the MAX3800 can restore high-frequency information that is 30dB down. The upper trace is the output of the cable that is applied to the input of the MAX3800. The lower trace of Figure 2 is the fully restored signal at the output of the MAX3800. Figures 3 through 6 are eye diagrams for the different cables operating at 2.5Gb/s. Figures 7 and 8 are eye diagrams for the FR4 sample operating at 2.5Gb/s.

## 5 Conclusion

Equalizing gigabit signals with the MAX3800 offers new distribution and interconnection possibilities to a world starving for more bandwidth.

**Table 1. Equalized Media Performance (PRBS-7)**

| Medium | Length (ft) | Bit Rate (b/s) | Deterministic Jitter (UI) |
|---|---|---|---|
| W.L. Gore–type 89 matched 50Ω coax pair | 115 | 3.2G | 0.04 |
| | | 2.5G | 0.03 |
| | | 622M | 0.01 |
| RG179B coax single-ended 75Ω | 100 | 3.2G | 0.16 |
| | | 2.5G | 0.09 |
| | | 622M | 0.04 |
| Belden 9207 twin-axial 100Ω | 100 | 3.2G | >0.67 |
| | | 2.5G | 0.20 |
| | | 622M | 0.04 |
| Madison #14887 shielded twisted-pair 100Ω | 50 | 3.2G | 0.16 |
| | | 2.5G | 0.12 |
| | | 622M | 0.02 |
| Stripline, FR4 6mil wide, 50Ω | 4.2 (50in) | 3.2G | 0.09 |
| | | 2.5G | 0.06 |
| | | 622M | 0.03 |

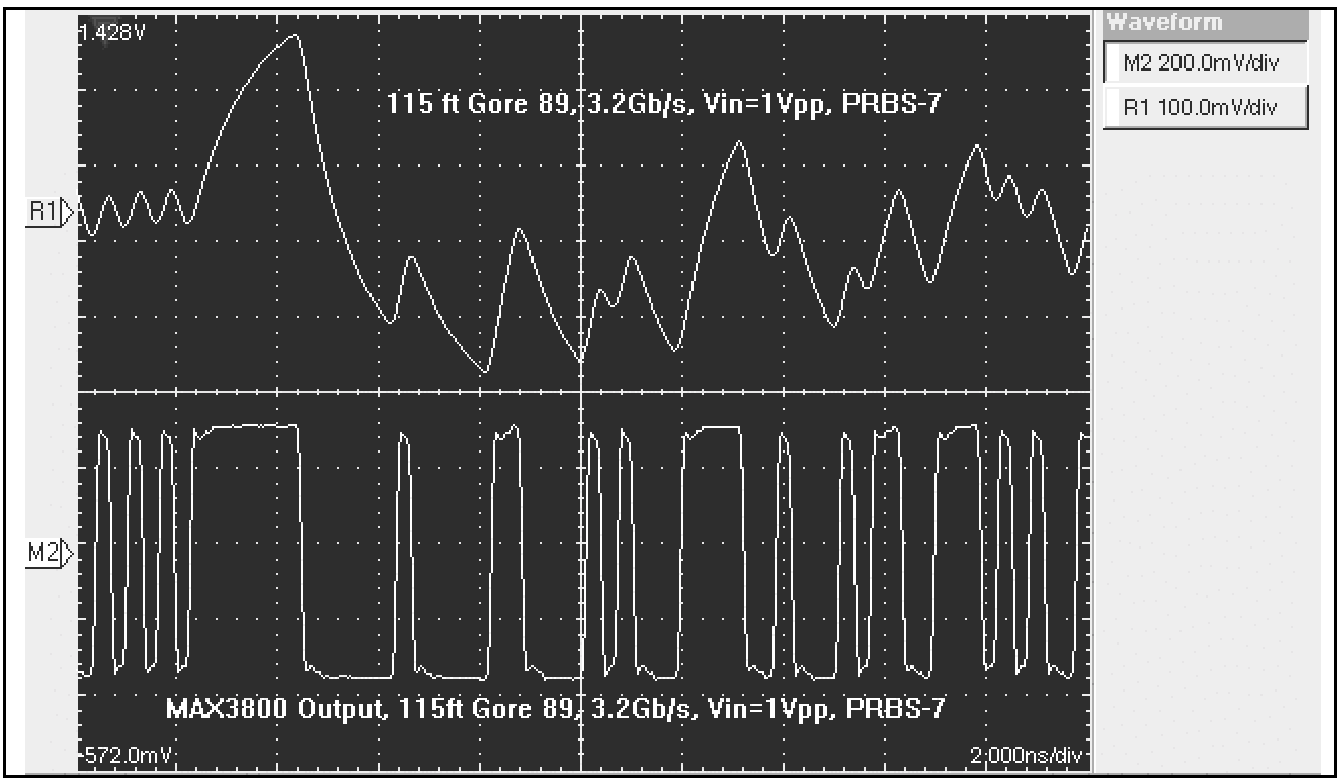


*Figure 2. Before and after equalization. The top trace is the 1Vp-p signal after traveling the 115ft length of the Gore-type 89 cable. Note the small ripples and bumps. These are single bits that have encountered 30dB of loss. The lower trace is after the upper trace was equalized by the MAX3800. All of the bits are fully restored.*

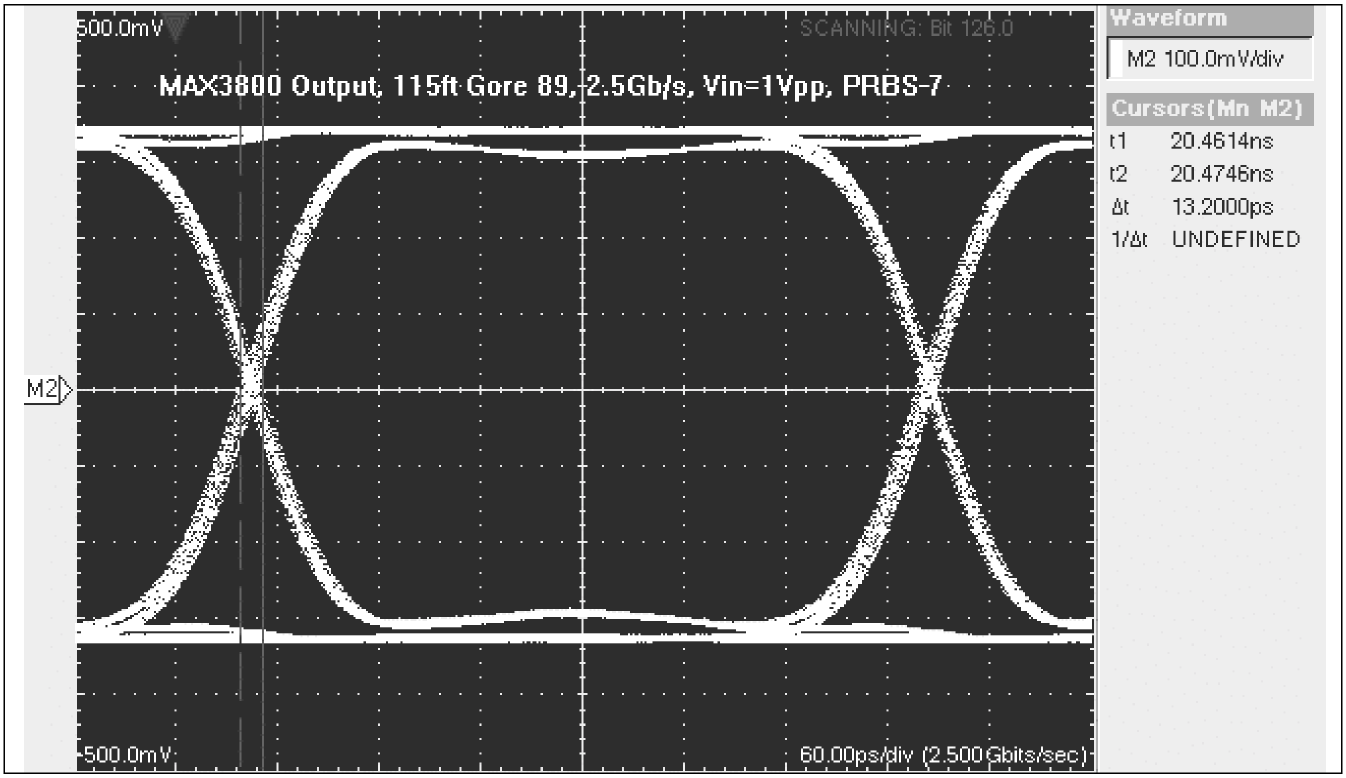


*Figure 3. After 115ft of Gore-type 89 cable, the restored signal has 13ps of deterministic jitter at 2.5Gb/s.*

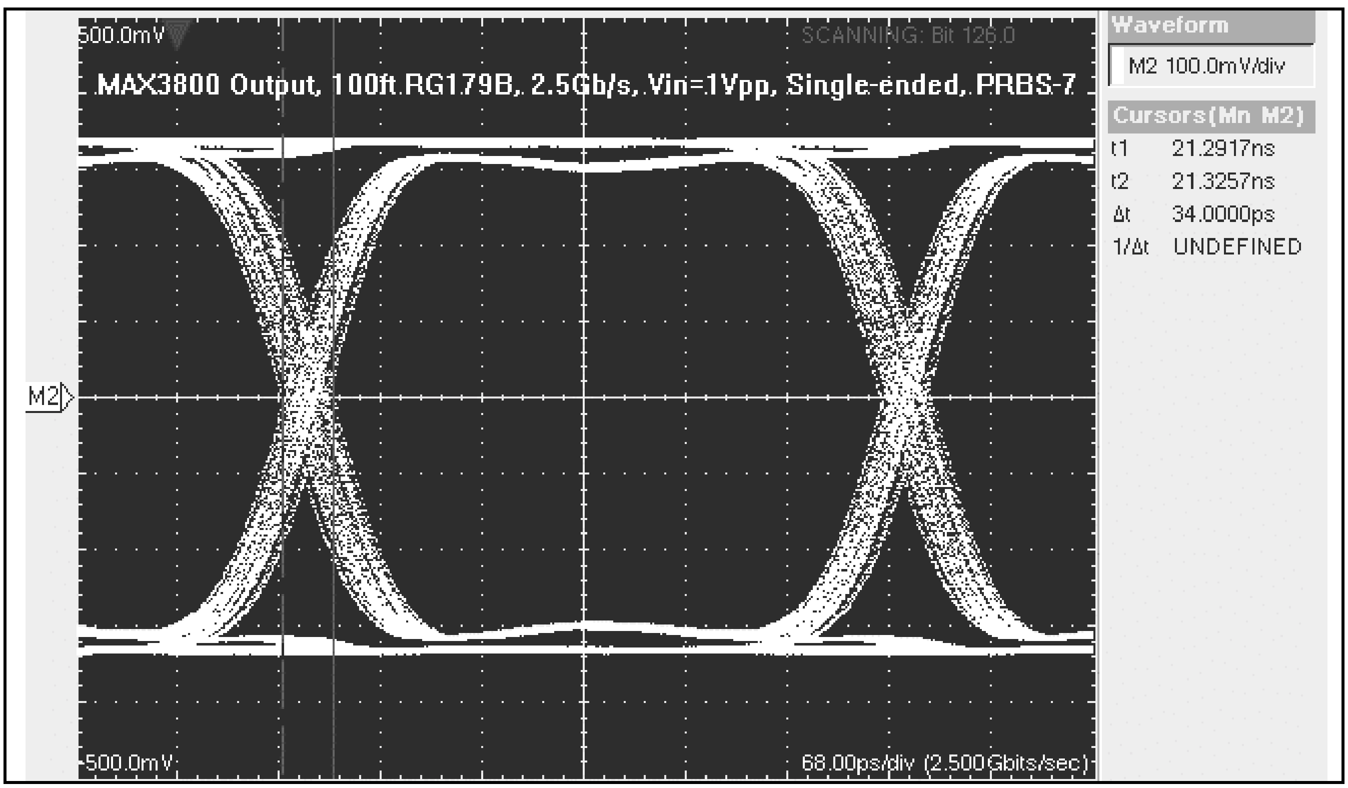


*Figure 4. After 100ft of RG179B, 75Ω cable, the restored signal has 34ps of deterministic jitter at 2.5Gb/s. The MAX3800 was driven in a single-ended fashion.*

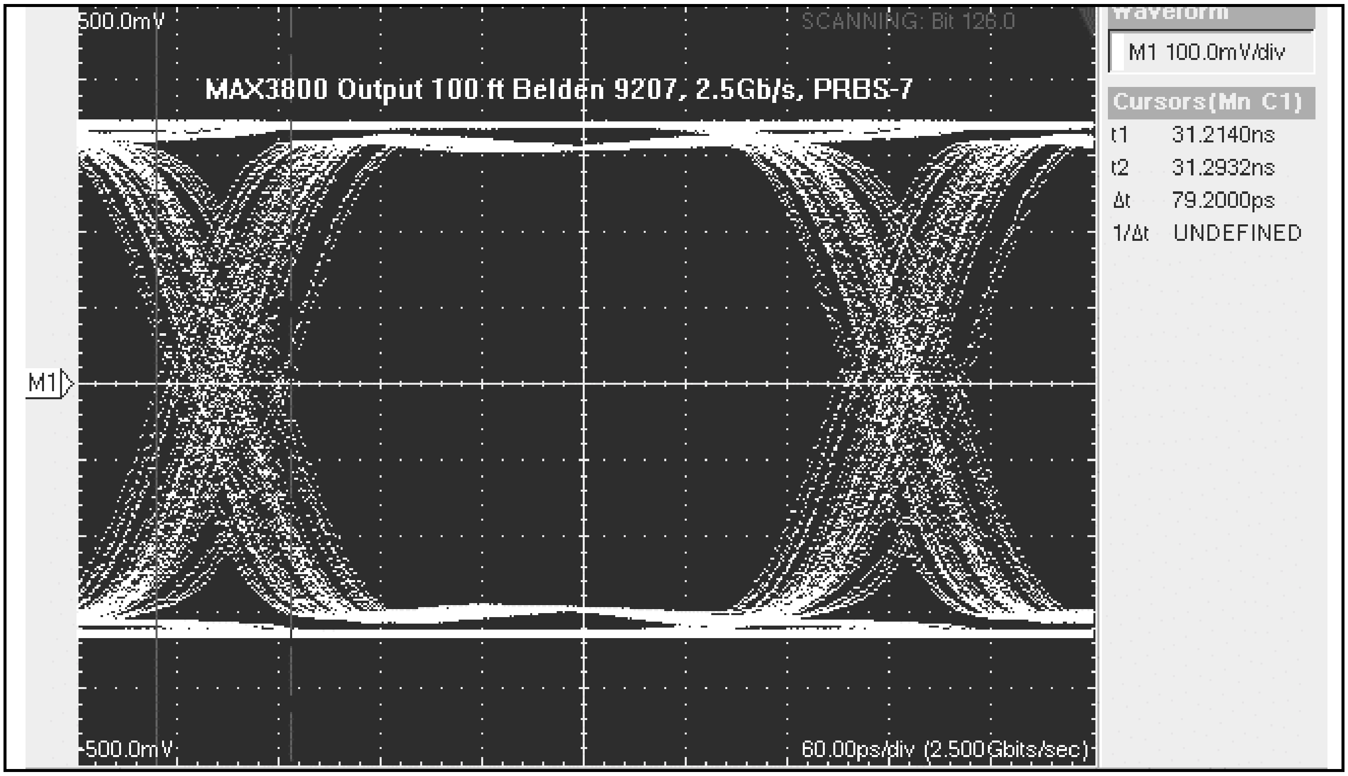


*Figure 5. After 100ft of 100Ω twin-axial cable, the restored signal has 79ps of deterministic jitter at 2.5Gb/s.*

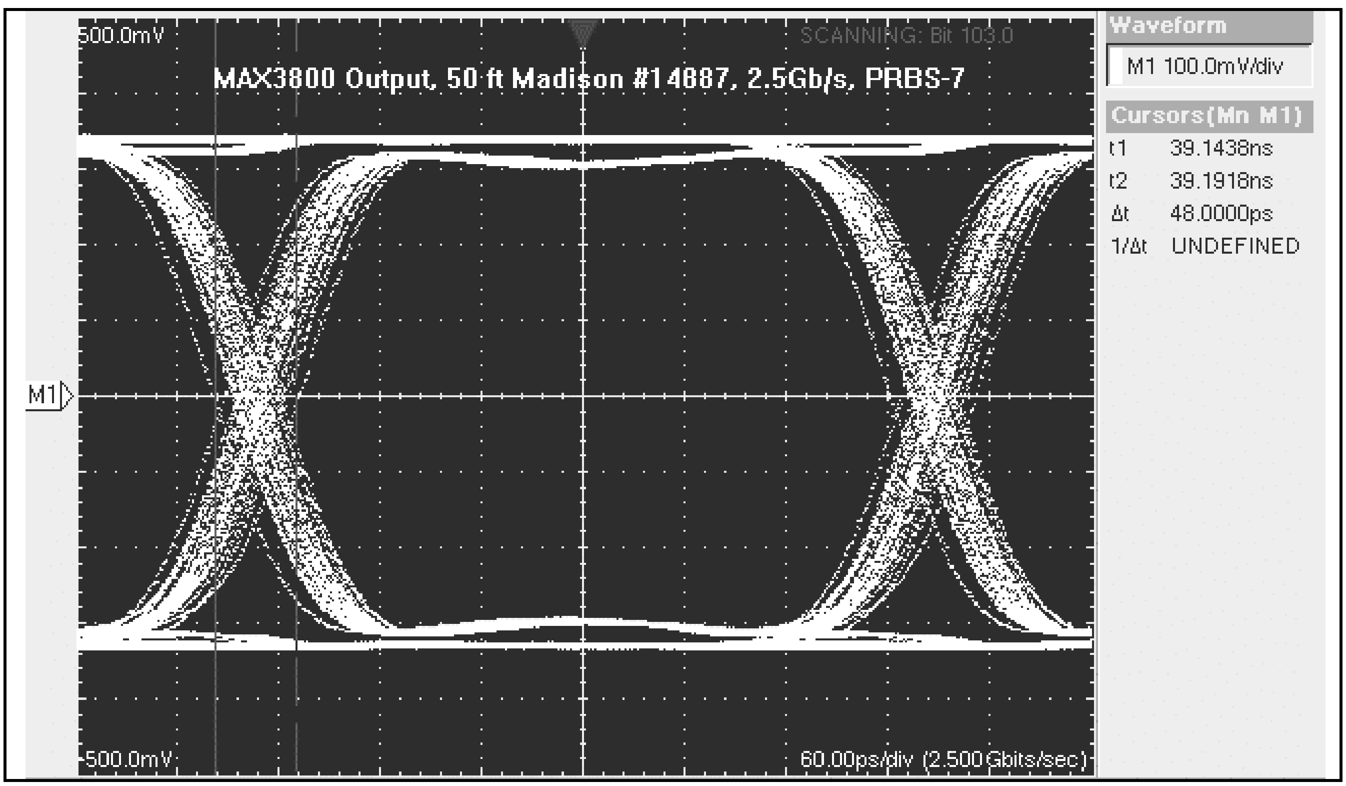


*Figure 6. After 50ft of 100Ω, shielded twisted pair, the restored signal has 48ps of deterministic jitter.*

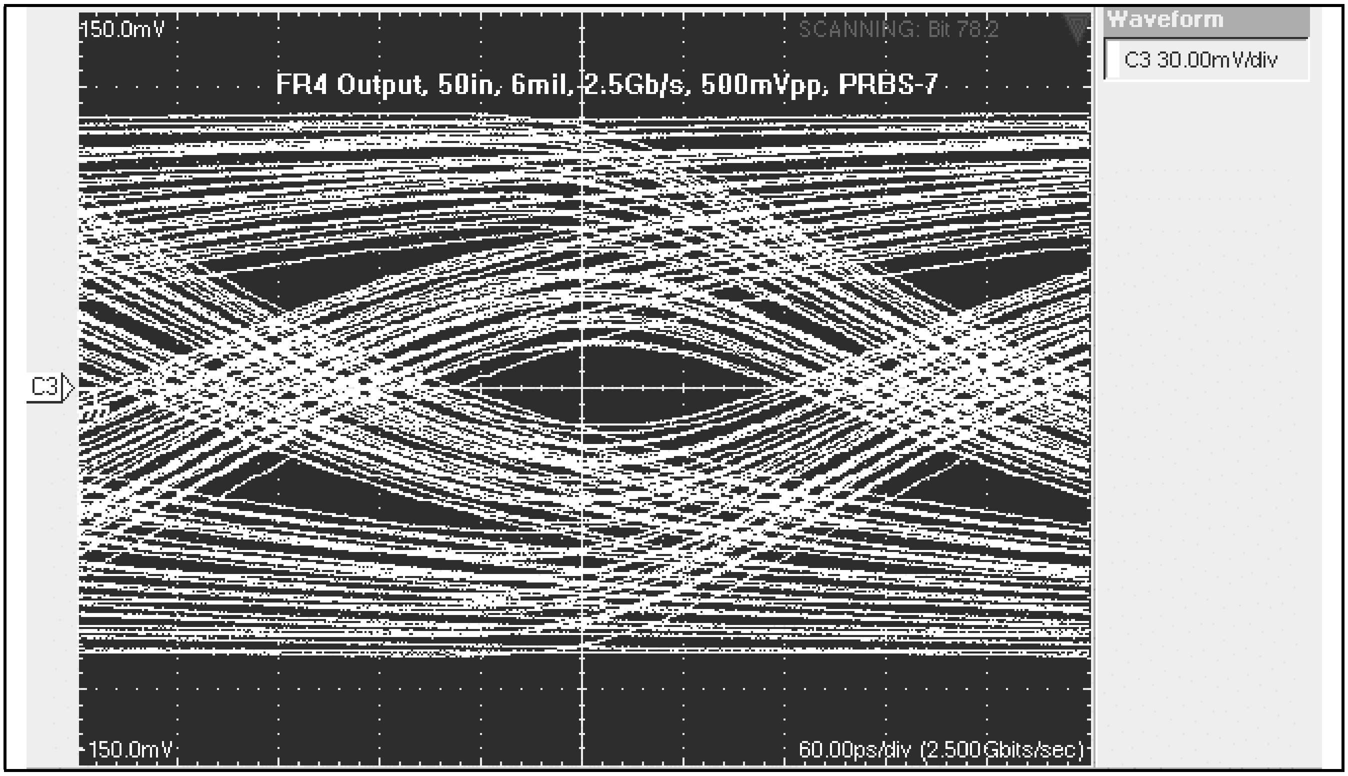


*Figure 7. Before equalization and after 4.2ft (50in) of FR4, 6mil-wide, 50Ω stripline, the input eye to the MAX3800 is nearly closed at 2.5Gb/s. The vertical opening is less than 30mVp-p.*

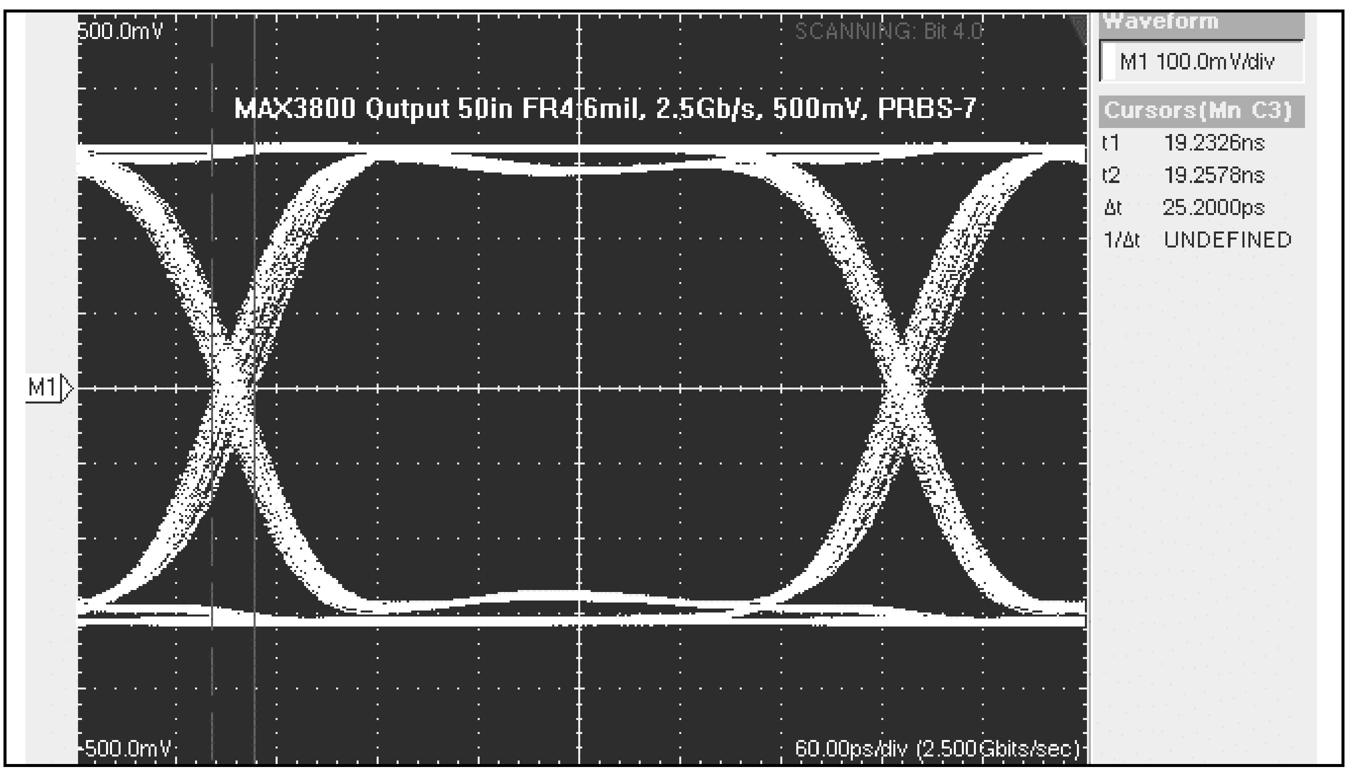


*Figure 8. After 50in of FR4, 6mil-wide, 50Ω stripline, the restored signal has 25ps of deterministic jitter at 2.5Gb/s.*