

# AN-1541 Driving Signals Over XAUI Backplanes Using DS42MB100, DS40MB200, or DS42BR400

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## ABSTRACT

This application report demonstrates how TI's DS42MB100, DS40MB200, and DS42BR400 equalize XAUI backplane FR4 traces and reduce data dependent jitter to within XAUI specifications.

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## 1 Introduction

The XAUI data rate is 3.125 Gbps with a nominal unit interval (UI) of 320 ps. IEEE 802.3ae specifies the maximum jitter budget for the interconnect to be 0.20 Ulp-p or 64ps (Clause 47.3.5, [Table 1](#)). The interconnect includes everything between the transmitter and receiver. For a backplane application, this includes short FR4 traces on line cards, line card to backplane connectors, and FR4 traces on the backplane. The maximum input jitter tolerance for the combined deterministic jitter and random jitter is 0.65 Ulp-p (Clause 47.3.4.6, [Table 1](#)). In many backplane applications, high frequency attenuation causes data dependent jitter to exceed the interconnect jitter budget and the input jitter tolerance. This application report demonstrates that using National's signal conditioning devices reduces jitter to meet XAUI input jitter tolerance and interconnect jitter budget requirements. This study also illustrates the effects of under and over equalization.

**Table 1. XAUI Jitter Budget Allowances.**

	DJ (Ulp-p)	TJ (Ulp-p)
Driver	0.17	0.35
Interconnect	0.2	0.2
Other - crosstalk, noise	0.1	0.1
Total	0.47	0.65

This study uses a Tyco HM-Zd XAUI Test Backplane. Note that different backplanes may have different attenuation characteristics and jitter results may vary. The information provided in this application report provides a performance reference for FR4 backplane applications. The jitter numbers reported are statistically extrapolated to 1e-12 BER.

## 2 Characteristics of a XAUI Backplane

At 3.125 Gbps (XAUI data rate), the skin effect and dielectric loss on the transmission media results in high-frequency signal attenuation. [Figure 1](#) shows the transmission loss for a 30 inch backplane at Giga-Hz frequencies. At the XAUI data rates, this equates to a -9 dB loss in operating bandwidth for the 30-inch XAUI backplane. In addition, the backplane connectors are weak links that introduce crosstalk. The crosstalk on the Tyco backplane is approximately -35dB.

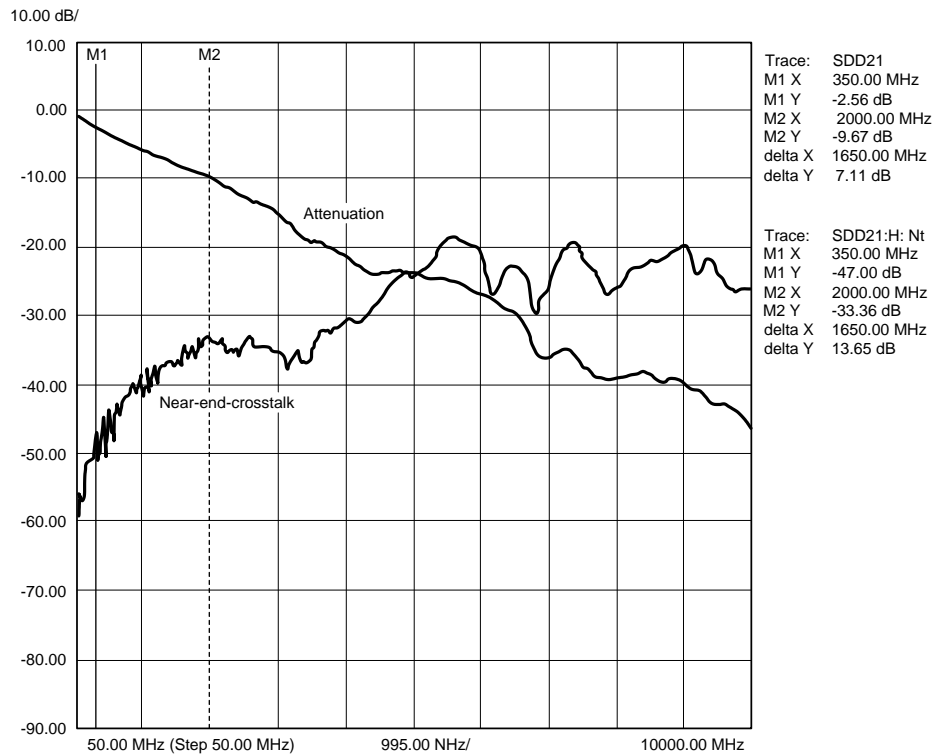


Figure 1. Attenuation and Crosstalk of the 30-Inch XAUI Backplane

### 3 Equalizing the 30-inch XAUI Backplane

There are two methods to equalize the attenuated signal over the backplane. One method is to use de-emphasis or pre-emphasis at the transmitter output. Another method is to use equalization at the receiver input. For a description of how equalization works, see application report 1473 (AN-1473).

Figure 2 is a functional block diagram of National's DS42MB100 Mux-Buffer with built-in signal conditioning capability. It is a bi-directional transceiver with high frequency equalization circuitry on each input that compensates up to 5dB of transmission loss at 2GHz. Each output has four levels of de-emphasis (up to -9dB) that can be utilized to match a specific channel's loss. Two pins are provided to set de-emphasis levels.

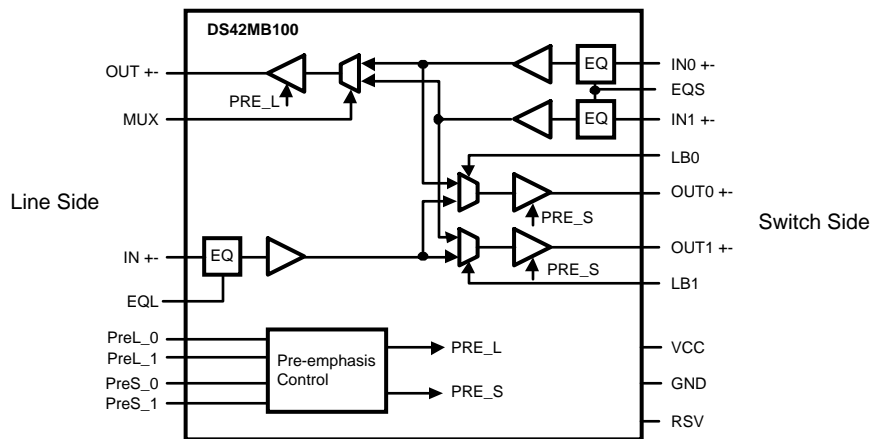


Figure 2. DS42MB100 Functional Diagram

In addition to signal conditioning capabilities, the DS42MB100 and DS40MB200 also have a built-in 2:1 multiplexer and 1:2 splitter for each bi-directional channel. This feature provides redundancy in backplane applications. Additionally, a loopback function on the switch side allows the transmitting data stream to loop back to its own receive path for additional troubleshooting flexibility.

The following information was collected using the DS42MB100 at 3.125 Gbps XAUI datarate; however, the test results are representative of the DS40MB200 and DS42BR400 as well since all three devices share the same core design and have similar performance characteristics.

#### 4 Equalizing the XAUI Backplane with Transmitter Output Signal Conditioning

Figure 3 shows the DS42MB100 at the transmitter side of the XAUI backplane. Since the XAUI transmission is bi-directional, asynchronous near-end-crosstalk (NEXT) is added to the receiver end. The transmitter at the driving end has the full amplitude while the receiver (that is, the DCA-J scope) on the same side receives an attenuated weak signal from the far-end transmitter. The NEXT caused by the transmitter output can superimpose onto the weak receive signal introducing additional jitter. Note that since the signal to crosstalk noise is 35 dB apart on the XAUI backplane the crosstalk adds less 2ps (peak-peak) jitter into the test channel.

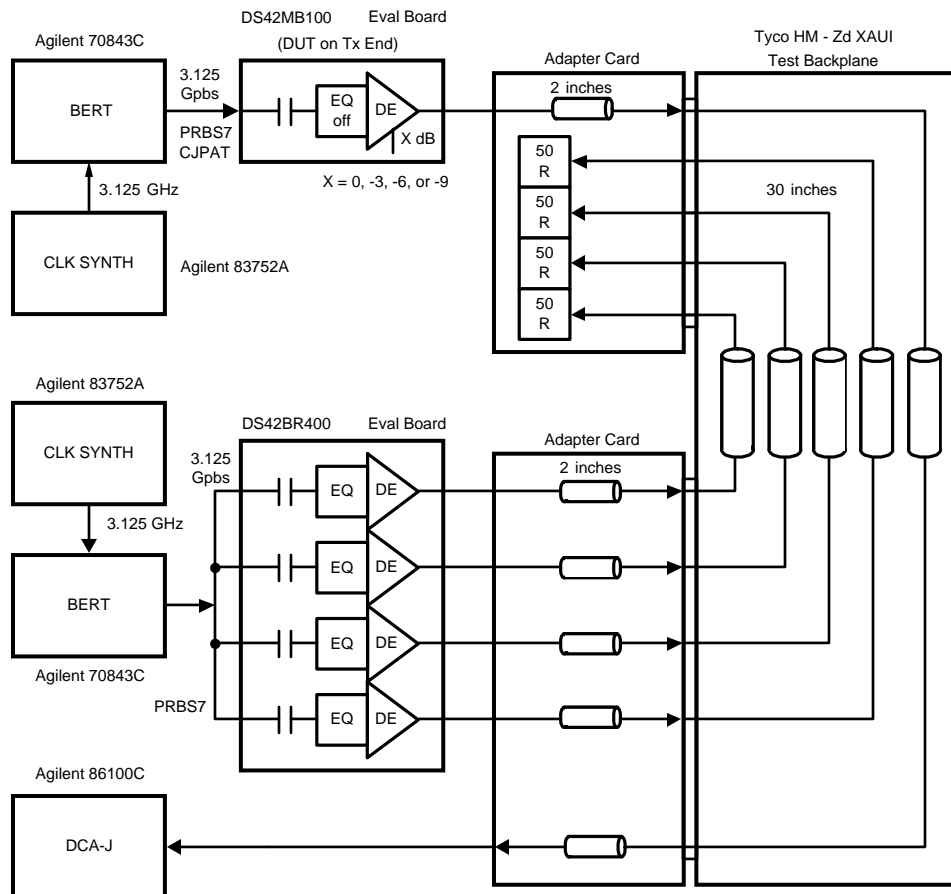
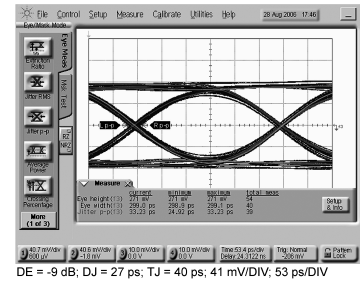
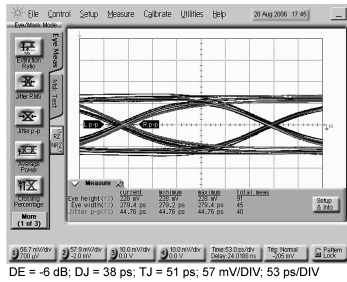
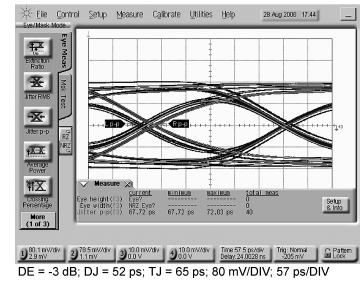
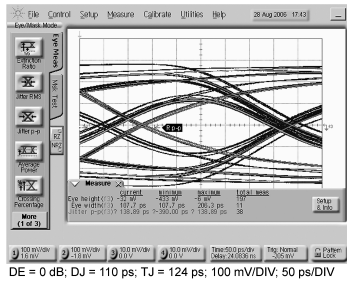


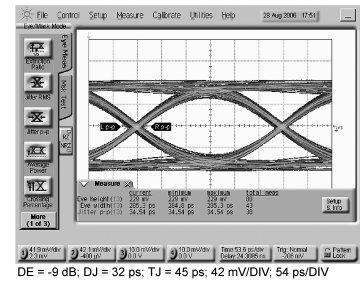
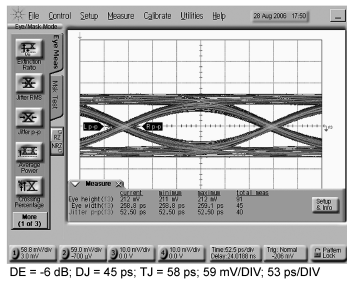
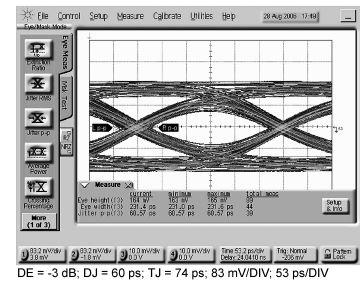
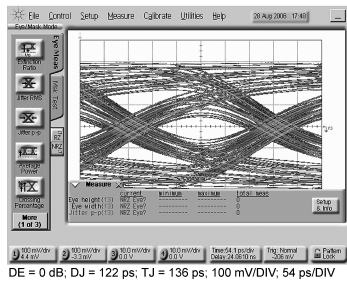
Figure 3. Transmitter Side Equalization Over the 30-inch XAUI Backplane

To simulate the XAUI operating environment, the test patterns used are Continuous Jitter Test Pattern (CJPAT) and pseudo-random bit stream (PRBS7). CJPAT is specified in the IEEE 802.3ae standard for jitter compliance testing. This pattern has large instantaneous phase jumps that can cause significant data dependent jitter. The PRBS7 pattern closely resembles 8B/10B coding but has a longer (7 instead of 5) string of consecutive identical digits (CIDs). It is a more stringent test pattern than standard 8B/10B coding. The test results are shown in [Figure 4](#).

**30-inch Backplane + Interface Cards; Pattern = CJPAT**



**30-inch Backplane + Interface Cards; Pattern = PRBS7**



**Figure 4. Transmitter Side Equalization Over the 30-inch XAUI Backplane (Note: Using de-emphasis brought the deterministic jitter down to well within the XAUI 64ps budget.)**

With transmitter side equalization, the optimal setting for the 30-inch backplane is -9dB de-emphasis. The effects of under equalization can be seen with 0dB, -3dB, and -6dB de-emphasis.

## 5 Equalizing the XAUI Backplane with Receiver Input Signal Conditioning

Figure 5 shows the same setup as Figure 3 except the signal conditioning component is placed at the receive end as a transmission line equalizer. The equalization boosts the high frequency content in the signal and reduces attenuation. The test results are shown in Figure 6.

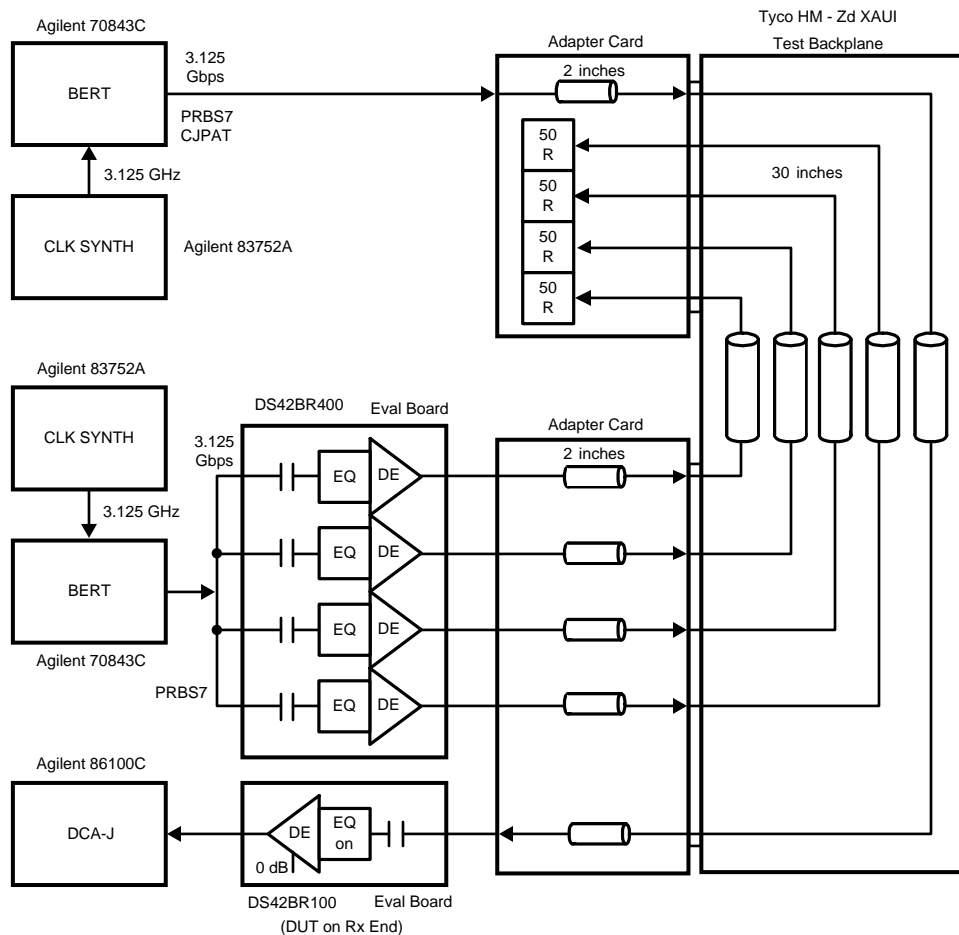
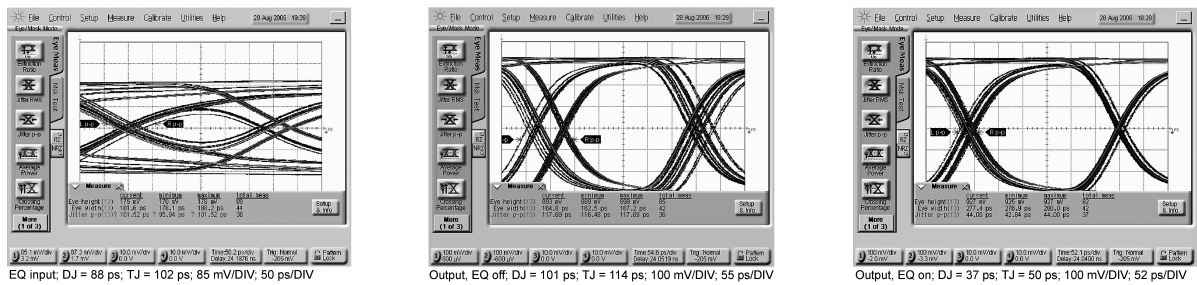


Figure 5. Receiver Side Equalization Over the 30-inch XAUI Backplane.

30-inch Backplane + Interface Cards; Pattern = CJPAT



30-inch Backplane + Interface Cards; Pattern = PRBS7

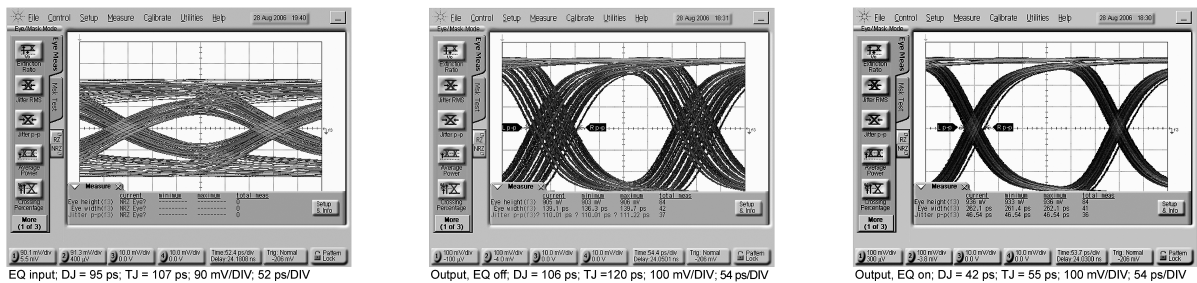


Figure 6. Receiver Equalization Over the 30-inch Backplane

When the receiver's equalizer is disabled, the deterministic jitter at the equalizer output is the sum of the input jitter plus any jitter added by the mux-buffer. Although the eye amplitude is restored by the mux-buffer, the total jitter at the output increases (Figure 6).

With receive equalization enabled, the high frequency content of the signal is boosted and the deterministic jitter reduces from 88 ps to 37 ps with a CJPAT pattern. For a PRBS7 pattern, the deterministic jitter reduces from 95 ps to 42 ps (Figure 6). This is well within the 64 ps (or 0.20UI) XAUI jitter budget. The equalizer not only reduces deterministic jitter but also restores the signal amplitude resulting in a lower bit error rate.

## 6 Equalizing The XAUI Backplane With Both Transmitter And Receiver Signal Conditioning

Figure 7 shows signal conditioning components placed on both the transmitter and receiver ends. In this case, the high frequency signal content is boosted before entering a lossy transmission line and then is boosted again after the transmission line. The test results are shown in Figure 8.

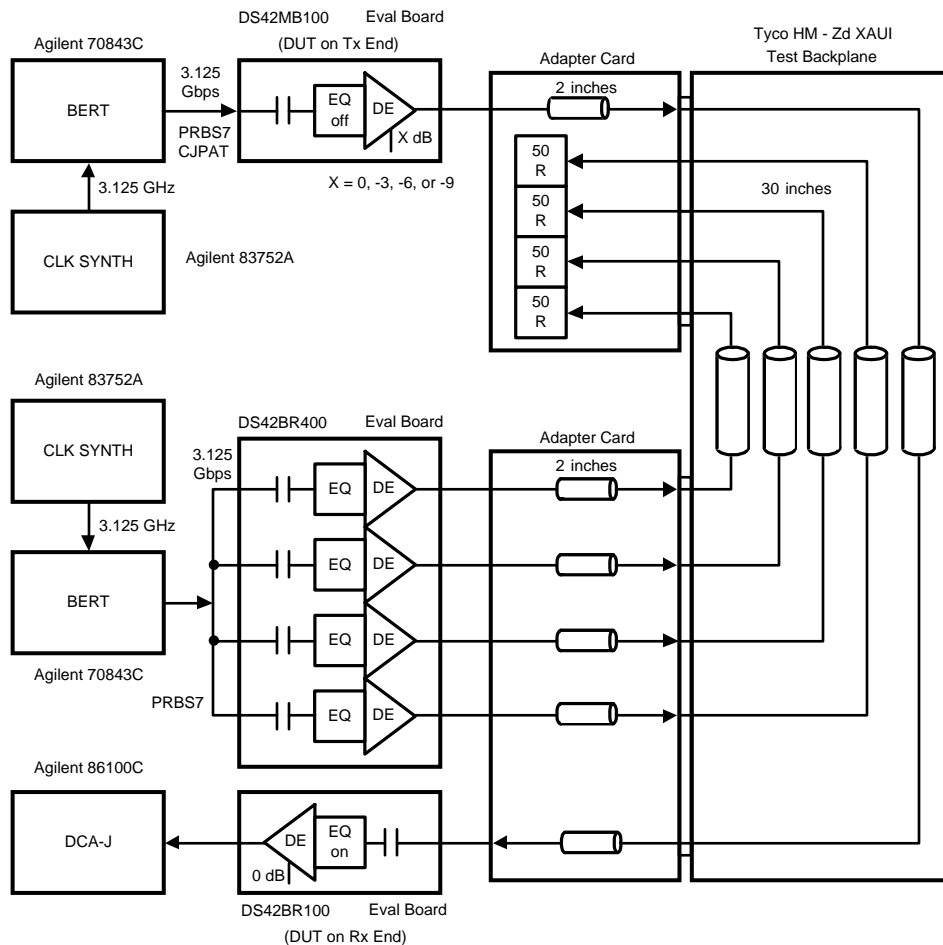
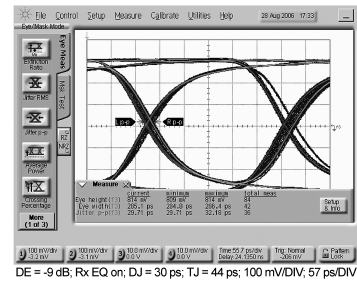
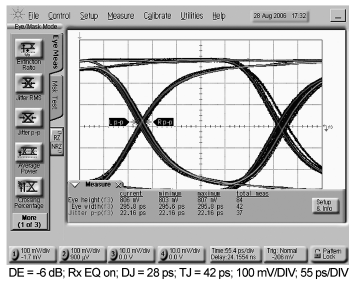
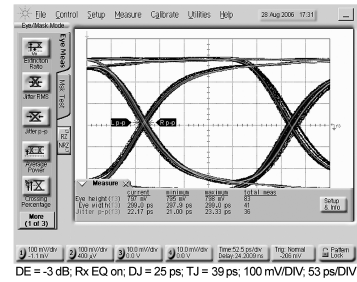
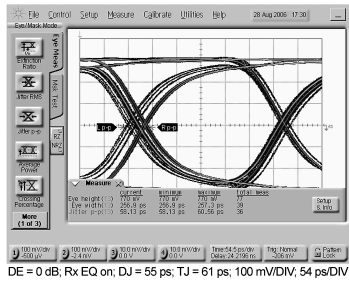


Figure 7. Transmitter and Receiver Equalization Over the 30-inch XAUI Backplane.



30-inch Backplane + Interface Cards; Pattern = CJPAT



30-inch Backplane + Interface Cards; Pattern = PRBS7

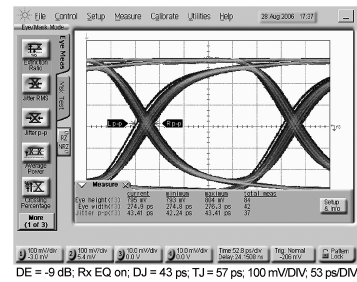
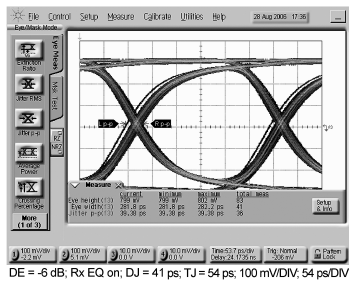
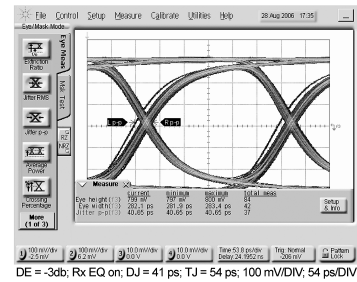
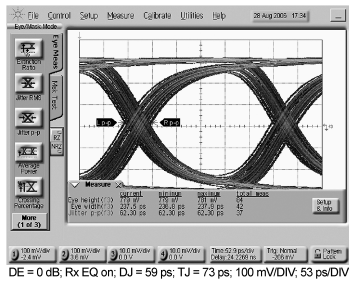


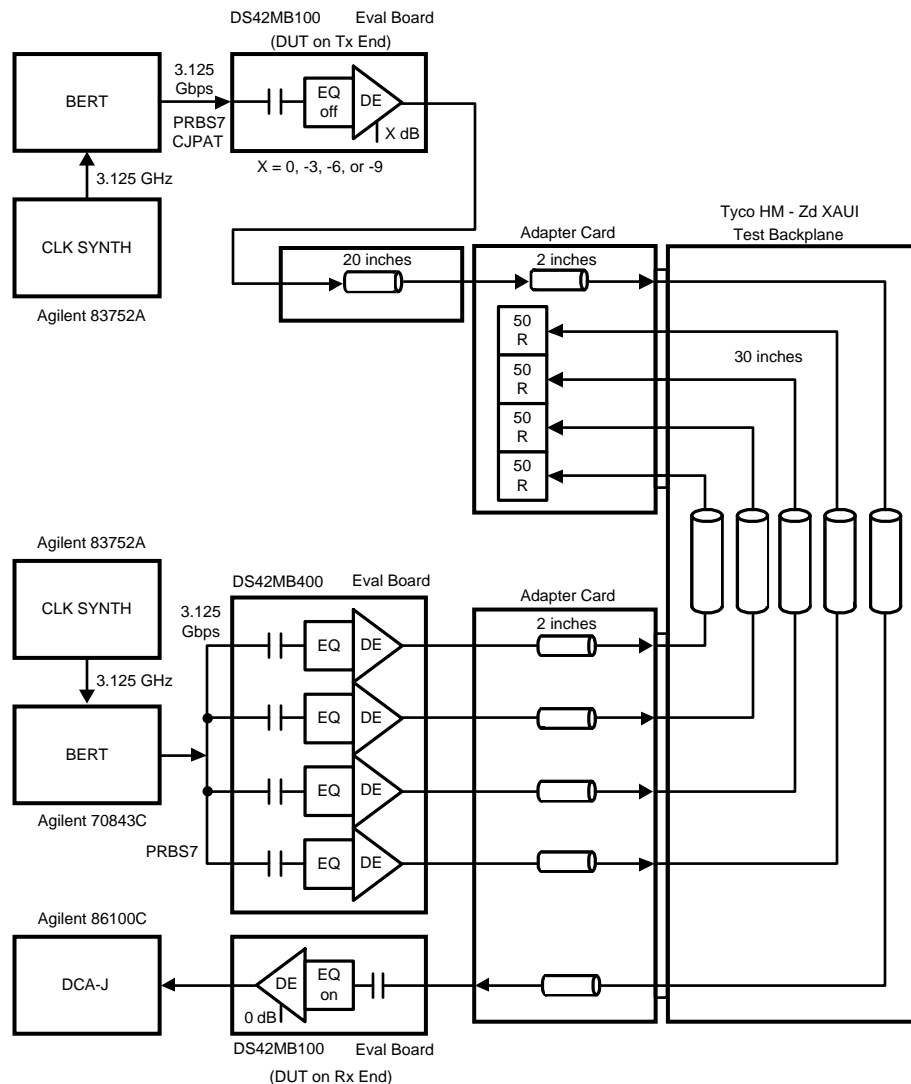
Figure 8. Signal Conditioning on Both Ends of the 30-inch Backplane

Compared with Figure 4, where the optimal setting is -9dB for transmitter side signal conditioning, Figure 8 shows the optimal setting for the 30-inch XAUI backplane is -3dB de-emphasis when an equalizer is used at the receive end. Having too much de-emphasis, such as -9dB, can create an over equalization situation and increase jitter. It is important to test a specific backplane for the optimal setting to achieve the lowest jitter.

As shown in Figure 8, over equalization (-9dB de-emphasis) indicates the transmitter can drive more than 30 inches of a XAUI backplane when using de-emphasis. There is enough performance head room built-in to compensate for higher channel loss. The following test shows the performance of a 20-inch FR4 attenuator board cascaded with the 30-inch XAUI backplane.

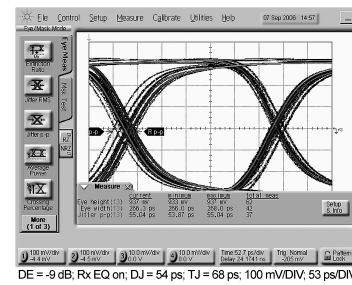
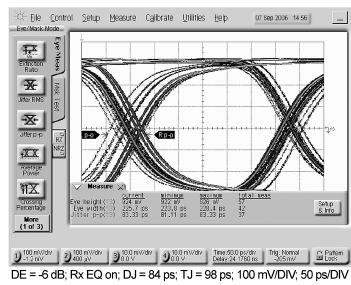
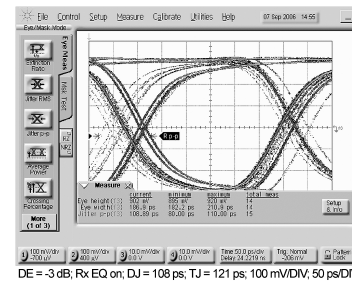
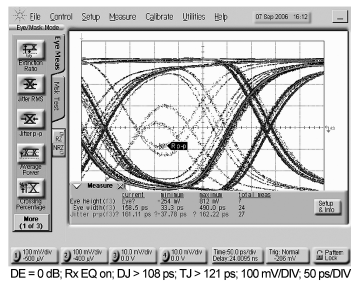
## 7 Equalizing the 30-inch XAUI Backplane With an Additional 20-inch FR4 Attenuation

Figure 9 resembles Figure 7 except an additional 20-inch, 5-mil, FR4 board is connected in series with the XAUI backplane. This transmission channel has much higher attenuation. The test results are shown in Figure 10.



**Figure 9. Transmitter and Receiver Equalization Over an Additional 20-inch FR4 and the 30-inch XAUI Backplane**

30-inch Backplane + Interface Cards; Pattern = CJPAT



30-inch Backplane + Interface Cards; Pattern = PRBS7

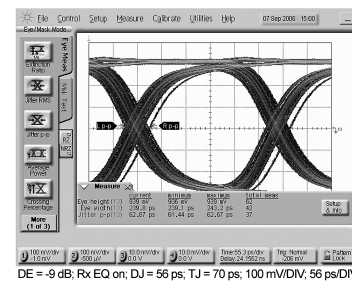
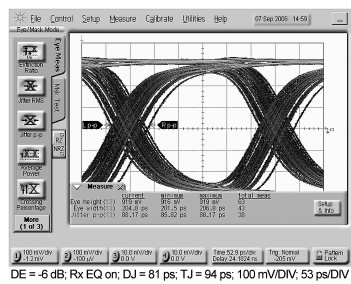
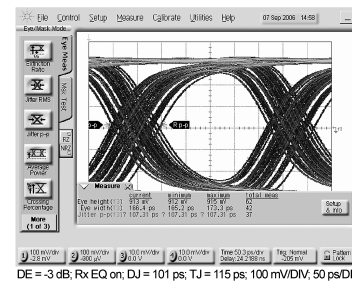
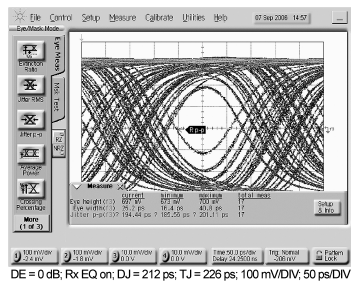


Figure 10. Signal Conditioning on Both Ends of the 20-inch FR4 and 30-inch Backplane

Figure 10 shows eye diagrams over more than 50 inches of FR4 trace and also shows that with 0dB de-emphasis and receive side equalization, the eye is almost closed. Applying -9dB de-emphasis combined with receiver equalization, the eye is restored and the deterministic jitter is reduced to below the XAUI 64ps (or 0.2UI) limit.

## 8 Conclusion

The DS42MB100, DS40MB200 and DS42BR400 signal conditioning devices are capable of equalizing the 30-inch XAUI backplane at one end of the backplane or on both ends of the backplane. Combining de-emphasis and equalization extends the channel reach over FR4 to more than 50 inches. It is also important to adjust the amount of equalization to match the channel loss to ensure the lowest amount of jitter is produced.

## 9 Texas Instruments Family of Signal Conditioning Devices for XAUI

*DS42MB100 4.25 Gbps 2:1/1:2 CML Mux/Buffer with Transmit Pre-Emphasis and Receive Equalization* ([SNLS244](#))

*Dual 4.0 Gbps 2:1/1:2 CML Mux/Buffer with Transmit Pre-Emphasis and Receive Equalization* ([SNLS144](#))

*DS42BR400 Quad 4.25 Gbps CML Transceiver with Transmit De-Emphasis and Receive Equalization* ([SNLS221](#))

*AN-1541 Driving Signals Over XAUI Backplanes Using DS42MB100, DS40MB200, or DS42BR400 Application Report* ([ZHCA262](#))

### XAUI Specification and References

<http://grouper.ieee.org/groups/802/3/ae/index.html>

<http://www.ieee802.org/3/>

<http://www.ethermanage.com/>

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