High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

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ABSTRACT

This application report focuses on characteristics of gigabit signals across different cable media, transmission distance, and Data Rates. The signal quality of four different cables is evaluated using eye measurements and TI’s TLK2500 evaluation modules (EVMs). This document provides guidance for cable selection to use with Texas Instruments line of gigabit parts.

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1 Introduction

The transmission line plays an important role in network communication. The signal quality is mainly decided by the cable performance. The general issue in communication’s cabling is the ability to handle the required Data Rate over a given distance. This report shows the customer the characteristics of gigabit signals across different cables via different lengths and Data Rates.

Four different cables are tested using the TLK2500EVM board with a TLK2500 multigigabit transceiver and an interface board for the cable test. The TLK2500 evaluation module (EVM) board is used to evaluate the TLK2500 for data transmission applications. All tests are performed at room temperature with nominal performing TLK2500 devices.

2 Base Line Eye Measurement

2.1 Description

This test is used to establish a base line eye measurement over three different R-Ref values and three different frequencies. The test uses the TLK2500EVM in test mode configured to generate $2^7-1$ PRBS (pseudo random bit stream) pattern.

TLK2500 offers the options for the voltage swing by adjusting reference resistor R_Ref and termination resistor Z. The equation for the de-emphasis is as follows.

$$V_{od}=(3.75/R_{Ref})*Z \text{ (in our case, } Z=50 \text{ for the transmission line)}$$

The theoretical values for the various R_Ref are as follows:

- $R_{Ref}=100 \quad V_{od}=1875 \text{ mv}$
- $R_{Ref}=200 \quad V_{od}=937.5 \text{ mv}$
- $R_{Ref}=500 \quad V_{od}=375 \text{ mv}$

2.2 Test Setup

The test set up for the baseline eye measurement is shown below:
Baseline testing will be tested at boundary conditions that represent maximum, nominal, and minimum high-speed serial output voltage swing. This will require changing R-Ref resistor to 100, 200, and 500 Ω.

2.3 Test Result

At normal ambient temperature, record eye measurements were recorded at different R-Ref values over various frequencies in the following table.

<table>
<thead>
<tr>
<th>R-Ref (Ohm)</th>
<th>1.6 Gbps</th>
<th>2.0 Gbps</th>
<th>2.5 Gbps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jitter (ps)</td>
<td>Vod (mV)</td>
<td>Jitter (ps)</td>
</tr>
<tr>
<td>100</td>
<td>82.8</td>
<td>1551.49</td>
<td>50.1</td>
</tr>
<tr>
<td>200</td>
<td>75.6</td>
<td>784.10</td>
<td>48.9</td>
</tr>
<tr>
<td>500</td>
<td>80.4</td>
<td>314.76</td>
<td>55.4</td>
</tr>
</tbody>
</table>
2.4 Conclusion

From the testing results, we can see that by selecting R_REF=100 for the test results in maximum output swing over the various Data Rates. Since cable length is more amplitude dependent than jitter dependent, 100 Ω was selected as the R_REF value for testing the different cable lengths. An R_REF=200 Ω was selected for the default on EVM measurements for optimum jitter.

Little discrepancy exists between the theoretical value we got from the formula and the test result. This is mainly due to the cable and connector insertion loss.

3 Cat5 Cable Eye Measurement

3.1 Description

This test is used to establish eye measurement over cable length and frequency. The test uses the TLK2500EVM in test mode configured to generate a PRBS pattern. The PRBS pattern will be sent across different cable lengths until a maximum length is reached. The maximum length is when the signal running over the cable length exhibits either a 60% eye closure or eye height drops below 200 mV Cable selection.

Since cable quality contributes strongly to signal quality, cable quality should be evaluated in detail. Three different cat5 cables were tested using TLK2500EVM.

- Cable A: BELDEN-E DATATWIST® 1585A
  CAT5, specified up to 200-MHz, blue cable in the following figure, to the left
- Cable B: BELDEN-M DATATWIST®1701A
  CAT5 (exceeding CAT5), specified up to 350 MHz, white cable in the following figure, in the middle
- Cable C: BELDEN-M MEDIATWIST® 1872A
CAT5 (exceeding CAT5), specified up to 350 MHz, red cable in the following figure, to the right.

Figure 3. Picture of the Cables

3.2 Test Setup

The picture of the above test setup follows.

Figure 4. Picture of the Test Setup
Figure 5. Cable Eye Measurement Test Setup

The interface board used for testing the Belden cable is an SMA-to-RJ45 adapter board (picture below).

Figure 6. Picture of the SMA-to-RJ45 Adapter Board
4 Test Result

4.1 1. Cable A - BELDEN-E DATATWIST® 1585A

Table 2. Cable A - Eye Measurement

| LENGTH (m) | 1.6 Gbps | | | 2.0 Gbps | | | 2.5 Gbps | | |
|---|---|---|---|---|---|---|---|---|
| Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) |
| 1 | 81.3 | 1343.91 | 65.4 | 1316.43 | 58.7 | 1183.16 |
| 2 | 88.0 | 1295.36 | 69.3 | 1037.05 | 56.0 | 1012.78 |
| 3 | 84.0 | 1243.15 | 65.8 | 1040.26 | 60.0 | 955.82 |
| 5 | 90.0 | 979.29 | 79.3 | 842.77 | 80.0 | 746.13 |
| 10 | 148.9 | 582.78 | 157.1 | 387.60 | 158.7 | 315.44 |
| 15 | 264.0 | 301.54 | 286.2 | 174.75 | NO DATA | 54.41 |

Jitter vs data rate

Eye height vs data rate

Figure 7. Jitter and Eye Height vs Data Rate of Cable A

4.2 2. Cable B - BELDEN-M DATATWIST ® 1701A

Table 3. Cable B - Eye Measurement

| LENGTH (m) | 1.6 Gbps | | | 2.0 Gbps | | | 2.5 Gbps | | |
|---|---|---|---|---|---|---|---|---|
| Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) |
| 1 | 82.0 | 1399.32 | 63.8 | 1251.72 | 62.7 | 1147.04 |
| 2 | 92.0 | 1267.05 | 65.3 | 1105.86 | 81.3 | 1109.37 |
| 3 | 88.0 | 1186.89 | 63.8 | 1099.73 | 73.3 | 960.43 |
| 5 | 96.0 | 1008.59 | 74.7 | 901.53 | 80.0 | 815.01 |
| 10 | 146.0 | 546.12 | 169.6 | 475.03 | 158.7 | 332.15 |
| 15 | 252.0 | 266.76 | # N/A | 103.75 | # N/A | # N/A |
4.3 3. Cable C - BELDEN-M MEDIATWIST ® 1872A

Table 4. Cable C - Eye Measurement

<table>
<thead>
<tr>
<th>LENGTH (m)</th>
<th>1.6 Gbps</th>
<th>2.0 Gbps</th>
<th>2.5 Gbps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jitter (ps)</td>
<td>Vod (mV)</td>
<td>Jitter (ps)</td>
</tr>
<tr>
<td>1</td>
<td>80.0</td>
<td>1327.65</td>
<td>71.6</td>
</tr>
<tr>
<td>2</td>
<td>84.0</td>
<td>1293.16</td>
<td>65.3</td>
</tr>
<tr>
<td>3</td>
<td>96.0</td>
<td>1227.02</td>
<td>65.3</td>
</tr>
<tr>
<td>5</td>
<td>98.0</td>
<td>1083.61</td>
<td>68.4</td>
</tr>
<tr>
<td>10</td>
<td>136.0</td>
<td>615.47</td>
<td>149.3</td>
</tr>
<tr>
<td>15</td>
<td>224.0</td>
<td>302.92</td>
<td>255.0</td>
</tr>
</tbody>
</table>

Figure 9. Jitter and Eye Height vs Data Rate of Cable C
4.4 Conclusion

In summary, the various characteristics of the cable tests are shown below.

**Figure 10. Jitter vs Cable Length**

**Figure 11. Vod vs Cable Length**

The eye height decreased with an increase in frequency and may be limited by rise time.
At short length, the PLL jitter improves with increasing the Data Rate, but on longer cable runs, the cable length will dominate the PLL jitter performance. We can see, at some given length, the jitter increased with increasing the Data Rate.

The amplitude loss is more significant than jitter in long distance transmission. This amplitude loss could have resulted due to connector reflections or cable loss.

From the test results of the four cables, we can see that the MediaTwist® 1872A cable is the best solution. It provides a maximum cable length of 10m at 2.5 Gbps.

5 Twinax Cable Eye Measurement

In this measurement, we chose Gore DXSN2095 twinax cable for testing. We used the same test setup except for the interface board. This time a Teradyne VHDM backplane open-ended differential interface board was used (part #494_5010-002).

The cable is shown in the figure12, and the interface board is shown in figure 13.

![Figure 12. Picture of Gore Twinax Cable](image)

![Figure 13. Interface Board](image)
Table 5.  Cable D - Eye Measurement

| LENGTH (m) | 1.6 Gbps |  | 2.0 Gbps |  | 2.5 Gbps |
|------------|----------|---|----------|---|----------|---|----------|---|----------|
|            | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) |
| 1          | 74.0       | 1416.87  | 59.1       | 1337.79  | 41.3       | 1353.12  |
| 5          | 76.0       | 1154.59  | 62.2       | 1022.12  | 52.0       | 947.81   |
| 15         | 126.0      | 528.13   | 110.4      | 400.26   | 117.3      | 266.89   |
| 20         | 182.0      | 293.36   | #N/A       | #N/A     | 183.45     | #N/A     | 86.97    |

Figure 14.  Jitter and Eye Height vs Data Rate of Cable D

Cat5 cable is cost effective vs Gore Twinax cable, but the Gore cable gives better performance. The Gore cable's maximum length is 15 m @ 2.5 Gbps.
References

1. DATATWIST® 5 – 1585A Specifications Rev.13E, Belden Technical papers Dec, 1999
2. DATATWIST® 350 – 1701A Specifications Rev.12, Belden Technical papers Dec, 1999
3. MEDIATWIST® 5 – 1872A Specifications Rev.6, Belden Technical papers Dec, 1999
Appendix

Figure 15. Eye Measurement @ R_Ref=100 Ohm Captured From HP83480A

Figure 15a. @ 1.6-GHz Data Rate

Figure 15b. @ 2.0-Gbps Date Rate
Figure 15c. @ 2.5-Gbps Data Rate

Figure 16. Eye Measurement @ R_Ref=200 O Captured From HP83480A

Figure 16a. @ 1.6-Gbps Data Rate

Figure 16b. @ 2.0-Gbps Data Rate
Figure 16c. @ 2.5-Gbps Data Rate

Figure 17a. @ 1.6-Gbps Data Rate

Figure 17b. @ 2.0-Gbps Data Rate
Figure 17c. @ 2.5-Gbps Data Rate

Figure 18a. @ 1.6-Gbps Data Rate

Figure 18b. @ 2.0-Gbps Data Rate

Figure 18. Cable A - Eye Measurement @ 1 m Captured From HP83480A
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

Figure 18c. @ 2.5-Gbps Data Rate

Figure 19. Cable A - Eye Measurement @ 2 m Captured From HP83480A

Figure 19a. @ 1.6-Gbps Data Rate

Figure 19b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

Figure 19c. @ 2.5-Gbps Data Rate

Figure 20. Cable A - Eye Measurement @ 3 m Captured From HP83480A

Figure 20a. @ 1.6-Gbps Data Rate

Figure 20b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

Figure 20c. @ 2.5-Gbps Data Rate

Figure 21. Cable A - Eye Measurement @ 5 m Captured From HP83480A

Figure 21a. @ 1.6-Gbps Data Rate

Figure 21b. @ 2.0-Gbps Data Rate
Figure 21c. @ 2.5-Gbps Data Rate

Figure 22. Cable A - Eye Measurement @ 10 m Captured From HP83480A

Figure 22a. @ 1.6-Gbps Data Rate

Figure 22b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rates

Figure 22c. @ 2.5-Gbps Data Rate

Figure 23a. @ 1.6-Gbps Data Rate

Figure 23b. @ 2.0-Gbps Data Rate
Figure 23c. @ 2.5-Gbps Data Rate

Figure 24. Cable B - Eye Measurement @ 1 m Captured From HP83480A
Figure 24a. @ 1.6-Gbps Data Rate
Figure 24b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

Figure 24c. @ 2.5-Gbps Data Rate

Figure 25. Cable B - Eye Measurement @ 2 m Captured From HP83480A

Figure 25a. @ 1.6-Gbps Data Rate

Figure 25b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

Figure 25c. @ 2.5-Gbps Data Rate

Figure 26. Cable B - Eye Measurement @ 3 m Captured From HP83480A

Figure 26a. @ 1.6-Gbps Data Rate

Figure 26b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rates

Figure 26c. @ 2.5-Gbps Data Rate

Figure 27a. @ 1.6-Gbps Data Rate

Figure 27b. @ 2.0-Gbps Data Rate

Figure 27. Cable B - Eye Measurement @ 5 m Captured From HP83480A
Figure 27c. @ 2.5-Gbps Data Rate

Figure 28. Cable B - Eye Measurement @ 10 m Captured From HP83480A
Figure 28a. @ 1.6-Gbps Data Rate

Figure 28b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rates

Figure 28c. @ 2.5-Gbps Data Rate

Figure 29. Cable B - Eye Measurement @ 15 m Captured From HP83480A

Figure 29a @ 1.6-Gbps Data Rate

Figure 29b. @ 2.0-Gbps Data Rate
Figure 29c. 2.5-Gbps Data Rate

Figure 30. Cable C - Eye Measurement @ 1 m Captured From HP83480A

Figure 30a. 1.6-Gbps Data Rate

Figure 30b. 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

Figure 30c. @ 2.5-Gbps Data Rate

Figure 31. Cable C - Eye Measurement @ 2 m Captured From HP83480A

Figure 31a. @ 1.6-Gbps Data Rate

Figure 31b. @ 2.0-Gbps Data Rate
Figure 31c. @ 2.5-Gbps Data Rate

Figure 32a. @ 1.6-Gbps Data Rate

Figure 32b. @ 2.0-Gbps Data Rate
Figure 32c. @ 2.5-Gbps Data Rate

Figure 33a. @ 1.6-Gbps Data Rate

Figure 33b. @ 2.0-Gbps Data Rate

Figure 33. Cable C - Eye Measurement @ 5 m Captured From HP83480A
Figure 33c. @ 2.5-Gbps Data Rate

Figure 34. Cable C -Eye Measurement @ 10 m Captured From HP83480A

Figure 34a. @ 1.6-Gbps Data Rate

Figure 34b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

Figure 34c. @ 2.5-Gbps Data Rate

Figure 35. Cable C - Eye Measurement @ 15 m Captured From HP83480A

Figure 35a. @ 1.6-Gbps Data Rate

Figure 35b. @ 2.0-Gbps Data Rate
Figure 35c. @ 2.5-Gbps Data Rate

Figure 36. Cable D - Eye Measurement @ 1 m Captured From HP83480A

Figure 36a. @ 1.6-Gbps Data Rate

Figure 36b. @ 2.0-Gbps Data Rate
High-Speed Gigabit Data Transmission Across Various Cable Media at Various Lengths and Data Rate

Figure 36c. @ 2.5-Gbps Data Rate

Figure 37. Cable D - Eye Measurement @ 5 m Captured From HP83480A

Figure 37a. @ 1.6-Gbps Data Rate

Figure 37b. @ 2.0-Gbps Data Rate
Figure 37c. @ 2.5-Gbps Data Rate

Figure 38. Cable D - Eye Measurement @ 15 m Captured From HP83480A

Figure 38a. @ 1.6-Gbps Data Rate

Figure 38b. @ 2.0-Gbps Data Rate
Figure 38c. @ 2.5-Gbps Data Rate

Figure 39. Cable D - Eye Measurement @ 20 m Captured From HP83480A

Figure 39a. @ 1.6-Gbps Data Rate

Figure 39b. @ 2.0-Gbps Data Rate
Figure 39c. @ 2.5-Gbps Data Rate
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