Channel Tuning Made Easy Using Linear Redrivers

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ABSTRACT

This report demonstrates the benefits of using Texas Instruments Linear Redrivers to simplify the process of channel tuning and improve system margins. Test results of the DS125BR820 linear redriver operating in various pre-channel and post-channel conditions are presented and show improvements in channel conditions in terms of transmitter pre- and post-cursor error-free operating region. This allows link training to more easily find an optimal operating point that is more robust against system variations. These results are applicable to other Linear Redriver devices in TI’s signal conditioning portfolio, including DS125BR111, DS125BR401A, and DS80PCI810.

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1 Introduction

The testing carried out in this report involves the DS125BR820 Low-Power 12.5 Gbps 8-Channel Linear Redriver, which is designed to support 40GbE (40G-CR4/KR4/SR4/LR4), 10GbE (10G-KR, SFF-8431), 12G SAS-3, PCIe Gen 3.0, and other applications up to 12.5Gbps. The linear nature of the DS125BR820’s equalization allows the DS125BR820 to preserve the transmit signal characteristics of the host ASIC, thereby allowing the host and the link partner ASIC to negotiate transmit equalizer coefficients during Link Training. These results are applicable to other Linear Redriver devices in TI’s signal conditioning portfolio, including DS125BR111, DS125BR401A, and DS80PCI810.

2 Pre-Channel and Post-Channel Performance Test

This test was conducted by varying the length of channel segments at the input and output of the DS125BR820, known as pre-channel and post-channel respectively. For each pre- and post-channel configuration, the transmitter pre- and post-cursor settings were swept, and the number of bit errors was recorded for 97 seconds (> 1E12 bits). In addition, baseline tests were conducted without the DS125BR820 Linear Redriver for different lengths of channel. The goal of this test was to compare the system’s region of error-free operation for a given total channel length with and without the DS125BR820.

2.1 Test Setup – Hardware

The ASIC transmitter output is connected to a trace board (pre-channel) and then to the input of the DS125BR820EVM. The output of the DS125BR820EVM is connected to another trace board (post-channel) followed by the ASIC receiver. In the no-redriver test case, the DS125BR820EVM is removed and replaced with two female-to-female SMA connectors, leaving only PCB trace between the transmitter and receiver. A diagram of the test setup with the redriver is shown in Figure 1. A diagram of the equivalent no-redriver test case is shown in Figure 2.

![Figure 1. Test Setup with DS125BR820EVM](image1)

![Figure 2. Test Setup without Redriver](image2)
2.1.1 DS125BR820EVM

The DS125BR820EVM SMA evaluation kit provides a complete platform to evaluate the signal conditioning features of the Texas Instruments DS125BR820 redriver. The DS125BR820EVM can be used for standards compliance testing, performance evaluation, and system prototyping. The equalization settings (EQ) and output differential amplitude (VOD) can be adjusted by strapping control pins to the proper logic levels, or register programming through SMBus serial interface.

![Figure 3. DS125BR820EVM Top Side](image)

2.1.2 ASIC Transmitter

A generic, commercially-available transmitter was used as the source of the 10.3125 Gbps and 12.5 Gbps PRBS31 data in this test. The differential output amplitude was configured to be 780 mV peak-to-peak. A frequency offset of ~210 ppm was introduced between the transmitter and receiver. The transmitter sweeps pre-cursor values from -3.1 dB to 0 dB (-15% to 0%) and post-cursor from -10.5 dB to 0 dB (-35% to 0%).

2.1.3 ASIC Receiver

A generic, commercially-available receiver was used to check the PRBS31 data for bit errors. This receiver has a continuous-time linear equalizer (CTLE) with up to 14 dB of equalization capability as well as a five-tap decision feedback equalizer (DFE). Both the CTLE and DFE are automatically adapted in real time to optimize the post-equalized eye height.

2.1.4 FR4 Microstrip Trace Boards

Various FR4 differential microstrip trace boards are used to mimic pre- and post-channel conditions of a real system. These boards vary in length from 5 to 40 inches (4 mil trace width) in steps of 5 inches.
2.2 Test Setup – Device Configuration

The settings used for the DS125BR820 Redriver in these tests are listed in Table 1. Lower EQ settings may be more suitable for shorter channel lengths.

<table>
<thead>
<tr>
<th>EQ SETTING</th>
<th>VOD SETTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>Pin Strap</td>
</tr>
<tr>
<td>Level 3</td>
<td>1 (1 kΩ to VIH)</td>
</tr>
</tbody>
</table>

(1) Each channel has its own EQ control register. Reg_0xF controls channel 0. Reg_0x16 controls channel 1, and so on.
(2) Each channel has its own VOD control register. Reg_0x10 controls channel 0. Reg_0x17 controls channel 1, and so on.
(3) VIH is nominally 2.5 V when the device is in 2.5-V Mode, or 3.3 V when the device is in 3.3-V Mode. For more details, see the electrical characteristics table of the device datasheet.

2.3 Results

The measurements are plotted in a matrix where the x-axis is the post-cursor value in decibels and the y-axis is the pre-cursor value in decibels applied by the ASIC TX. The total error count during the 97 second test is shown in each point and is color coded to represent the total error range. Green means there were zero errors, and red represents the maximum number of the error counter, 4,095. Some examples can be seen in Figure 6 through Figure 11. For all of the data with various channel configurations, see Appendix A and Appendix B.

![Figure 4. 40" (-33.9 dB) Channel No-Redriver](image)
![Figure 5. 5" (-5.7 dB) Pre- and 35" (-31.9 dB) Post-channel with Redriver](image)
Figure 6. 45" (-38.2 dB) Channel
No-Redriver

Figure 7. 5" (-5.7 dB) Pre- and 40" (-35.3 dB) Post-channel
with Redriver

Figure 8. 30" (-31.2 dB) Channel
No-Redriver

Figure 9. 5" (-6.8 dB) Pre- and 25" (-27 dB) Post-channel
with Redriver

Figure 10. 35" (-36 dB) Channel
No-Redriver

Figure 11. 10" (-11.9 dB) Pre- and 25" (-27 dB) Post-channel
with Redriver
**NOTE:** In addition to comparing the performance of with-redriver and no-redriver cases for similar total channel lengths, no-redriver tests with a given channel length were compared to with-redriver tests with a longer channel length for the purposes of demonstrating channel reach extension. This is shown in Figure 12 and Figure 13 (35” against 45” at 10.3125 Gbps), and Figure 14 and Figure 15 (30” against 35” at 12.5 Gbps).

**Figure 12.** 35” (-30.5 dB) Channel
No-Redriver

**Figure 13.** 5” (-5.7 dB) Pre- and 40” (-35.3 dB) Post-channel
with Redriver

**Figure 14.** 30” (-31.2 dB) Channel
No-Redriver

**Figure 15.** 10” (-11.9 dB) Pre- and 25” (-27 dB) Post-channel
with Redriver
3 Conclusions

The DS125BR820 Linear Redriver shows a clear improvement in the size of the error-free region for a given channel length, as shown in Figure 4 through Figure 11. This increase in system margin is a great advantage because link training happens very quickly and the resulting operating point may not be optimal due to normal run-to-run variations. Having a larger error-free operating region is helpful to ensure best chances of link training finding an error-free operating point. Having a larger error-free region is also beneficial because the system characteristics may change over time due to ambient temperature changes or voltage supply fluctuations.

Furthermore, Figure 12 through Figure 15 shows it is possible to extend the overall channel reach of the system by utilizing TI’s linear redrivers. At both 10.3125 Gbps and 12.5 Gbps, similar system margins were obtained with up to 10 dB additional insertion loss as a result of using the DS125BR820 Linear Redriver.

TI’s Linear Redrivers add system flexibility thereby relaxing the requirements for the ASIC and simplifying the process of channel tuning. This can provide advantages in overall system cost, power consumption, and time to market.
The following figures show a comparison between the error count matrices for the with and without redriver cases for 10.3125 Gbps. Note that 4,095 is the maximum number of errors and the loss in decibels includes the trace losses of the EVM and all other parts of the test fixture.

Figure 16. 40" (-33.9 dB) Channel No-Redriver

Figure 17. 5" (-5.7 dB) Pre- and 35" (-31.9 dB) Post-Channel with Redriver

Figure 18. 40" (-33.9 dB) Channel No-Redriver

Figure 19. 15" (-14.5 dB) Pre- and 25" (-22.9 dB) Post-Channel with Redriver
Appendix A

Figure 20. 40" (-33.9 dB) Channel No-Redriver

Figure 21. 25" (-22.9 dB) Pre- and 15" (-14.5 dB) Post-No-Redriver channel with Redriver

Figure 22. 40" (-33.9 dB) Channel No-Redriver

Figure 23. 35" (-31.9 dB) Pre- and 5" (-5.7 dB) Post-No-Redriver channel with Redriver

Figure 24. 45" (-38.2 dB) Channel No-Redriver

Figure 25. 5" (-5.7 dB) Pre- and 40" (-35.3 dB) Post-No-Redriver channel with Redriver
Figure 26. 45" (-38.2 dB) Channel No-Redriver

Figure 27. 15" (-14.5 dB) Pre- and 30" (-27.9 dB) Post-Channel with Redriver

Figure 28. 45" (-38.2 dB) Channel No-Redriver

Figure 29. 30" (-27.9 dB) Pre- and 15" (-14.5 dB) Post-Channel with Redriver

Figure 30. 45" (-38.2 dB) Channel No-Redriver

Figure 31. 40" (-35.3 dB) Pre- and 5" (-5.7 dB) Post-Channel with Redriver
The following figures show a comparison between the error count matrices for the with and without redriver cases for 12.5 Gbps. Note that 4,095 is the maximum number of errors and the loss in decibels includes the trace losses of the EVM and all other parts of the test fixture.

![Figure 32. 30" (-31.2 dB) Channel No-Redriver](image1)

![Figure 33. 5" (-6.8 dB) Pre- and 25" (-27 dB) Post-channel with Redriver](image2)

![Figure 34. 30" (-31.2 dB) Channel No-Redriver](image3)

![Figure 35. 10" (-11.9 dB) Pre- and 20" (-22.1 dB) Post-channel with Redriver](image4)
Figure 36. 30" (-31.2 dB) Channel
No-Redriver

Figure 37. 20" (-22.1 dB) Pre- and 10" (-11.9 dB) Post-Channel
with Redriver

Figure 38. 30" (-31.2 dB) Channel
No-Redriver

Figure 39. 25" (-27 dB) Pre- and 5" (-6.8 dB) Post-Channel
with Redriver

Figure 40. 35" (-36 dB) Channel
No-Redriver

Figure 41. 5" (-6.8 dB) Pre- and 30" (-32.9 dB) Post-Channel
with Redriver
Figure 42. 35" (-36 dB) Channel
No-Redriver

Figure 43. 10" (-11.9 dB) Pre- and 25" (-27 dB) Post-
No-Redriver channel
with Redriver

Figure 44. 35" (-36 dB) Channel
No-Redriver

Figure 45. 25" (-27 dB) Pre- and 10" (-11.9 dB) Post-
No-Redriver channel
with Redriver

Figure 46. 35" (-36 dB) Channel
No-Redriver

Figure 47. 30" (-32.9 dB) Pre- and 5" (-6.8 dB) Post-
channel
with Redriver
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- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
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