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Tuning Linear Redrivers Application Note

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APPLICATION NOTE

Abstract

This application note describes the basics for properly tuning linear redrivers. Linear redrivers are used in systems in order to improve high speed signal integrity in systems transmitting digital data.

INTRODUCTION

Linear redrivers are used in many applications that transmit data at high speeds. They can be found on computer motherboards, gaming consoles, graphics cards, cables, and any other environment that transmits digital data. More specific examples of common applications using linear redrivers include USB, DisplayPort, HDMI, PCIe, and SATA ports.

These applications can send data from 5 Gbps to 12 Gbps contingent on the standard. As data rates increase, signal integrity degenerates from PCB traces, transmission cables, and inter−symbol interference (ISI). The signal degradation caused by these deterministic jitter sources must be corrected in order to reduce bit errors and to perform proper data transmission.

Many designers depend on signal repeaters to correct the linear losses that occur naturally in systems. Linear redrivers are a category of signal repeaters that provide analog gain to digital signals. The linear gain from these devices do not interfere with complex link training and make them easy to integrate into systems. Devices such as linear repeaters help to reduce the deterministic jitter and can reduce the total apparent loss.

When discussing system losses, they are most often expressed in decibels (dB). Loss is represented in decibels in order to simplify the characteristics that contribute to the total losses. These decibel values are represented as a function of the original signal and are calculated simply by the gain equation, Gain−dB = 20 Log (Vout / Vin) dB. For example; if a signal has a voltage amplitude of 600 mV and after some unknown loss the output signal is 300 mV, it can be calculated that the loss is −6 dB by using the equation −6 dB = 20 Log ((300 mV) / (600 mV)) dB. Due to this relationship, we do not need to know anything about what hinders the original signal, such as trace length, board capacitance, or any other parameter that may affect the output signal amplitude.

Most redrivers use common and reliable methods to eliminate these losses. The most important characteristics of these devices are the equalization, the flat gain, and the output compression. These characteristics can vary from manufacturer and between devices, but generally work to the same affect.

The first and most important characteristic is the equalization, which is a form of linear gain that increases with frequency. The equalization is the principal method redrivers use to correct the signal losses. At higher frequencies and data rates, the loss of a signal is distinctively more than at low frequency. The equalization of a repeater will make the higher frequency signals match the amplitude of the low frequency signals by providing the correct amount of gain to equalize them. See Figure 1 for the plot of equalization on a logarithmic scale.

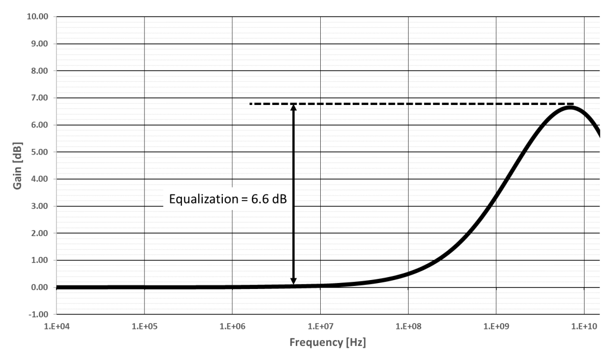

Figure 1. Equalization Gain Plot across Frequency

The second notable characteristic of redrivers is regularly termed the flat gain. The flat gain simply adjusts the overall amplitude of all frequencies by providing a fixed gain across the entire frequency range. More simply, the flat gain is normally used to increase the complete signal amplitude. See Figure 2 for the plot of flat gain on a logarithmic scale.

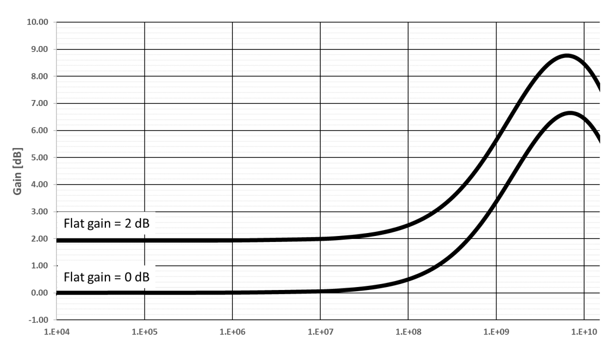

Figure 2. Flat Gain Plot across Frequency

The final redriver characteristic that is important to remember is the output compression. The output compression refers to the maximum signal amplitude at the output of the redriver. Normally this is defined by the negative 1 dB compression point. This value indicates that the output will begin to attenuate if the input is driven passed this point. See Figure 3 for a plot of output compression.

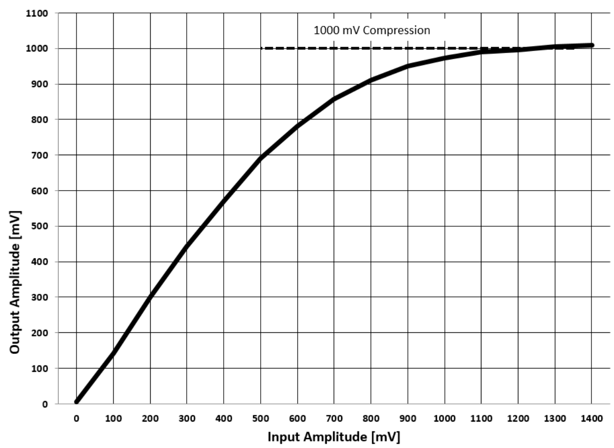

Figure 3. Output Compression − Input vs. Output Voltage

These redriver features can be easily monitored and adjusted by viewing the digital signals eye diagram. Eye diagrams are created by overlaying the bits of a digital signal that are made up of different data rates. A very common signal that is used to do this is called a pseudo random pattern.

The pseudo random pattern is similar to real life data transfers, in the sense that it is composed of different data rates. In all data transfers, whether they be from HDMI, USB, or DisplayPort, they send packets and bit streams that are composed of many different data rates that depend highly on the information being sent.

Eye diagrams are excellent indicators of a data signals quality. You can see the low frequency components of the signal, the high frequency components of the signal, and the jitter all in a single waveform. The key measurements to look for signal quality in an eye diagram are the eye height, the eye width, and amplitude. The eye height directly reflects the high frequency data signal amplitude and can be adjusted by using redriver equalization. The eye width can show the jitter, rise time, and fall time of the signal. The amplitude of the eye diagram reveals the low frequency signal amplitudes. The eye diagram seen in Figure 4, shows an eye diagram that was created using a pseudo random pattern and the key measurements.

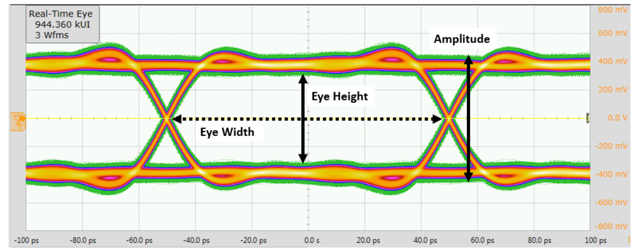

Figure 4. Eye Diagram Key Measurements

Tuning Redriver Equalization

Redrivers frequently support a selectable equalization architecture that allows for different equalization settings to pick from. These equalization ranges are always defined as decibel values at the highest supported frequency of the standard the redriver is intended for. A direct example of this are USB redrivers. USB 3.1 systems support data rates up to 10 Gbps, which has a transmission frequency of 5 GHz at its fastest transfer rate. When using USB 3.1 redrivers, the equalization is defined at 5 GHz as this is the frequency with the highest loss in the system. When reviewing the documentation for these devices they will represent the supported equalizations in a table as some dB @ 5 GHz.

When selecting the equalization value, it is important to match the dB gain with the dB loss of the system. If a system has −6 dB of loss at 5 GHz, the redriver selected equalization should be close to this value in order to recover the signals. In an ideal system if the redriver being used had 6 dB of equalization at 5 GHz, the signal would be perfectly recovered to match the original input signal.

In the real word application of these devices there will always be a minor mismatch in the losses to the redriver equalization and slight adjustments to the equalization settings will need to be made to recover the signals more precisely. For example, it could be that the redriver equalization setting of 7 dB actually recovers the signal of the −6 dB of losses better than its 6 dB setting for equalization. It is essential to review the eye diagram of the signals while adjusting the redriver settings to ensure the setting matches the loss closely. The correct settings have been achieved when the eye height and amplitude match closely.

Figure 5 shows the block diagram of the testing set up and location of the signals. In Figure 6 and Figure 7, the eye diagram of a signal before and after −6 dB of linear losses can be seen. These signals are then recovered by a linear redriver that is using too low of an equalization setting and finally the correctly tuned value of equalization, see Figure 8 and Figure 9.

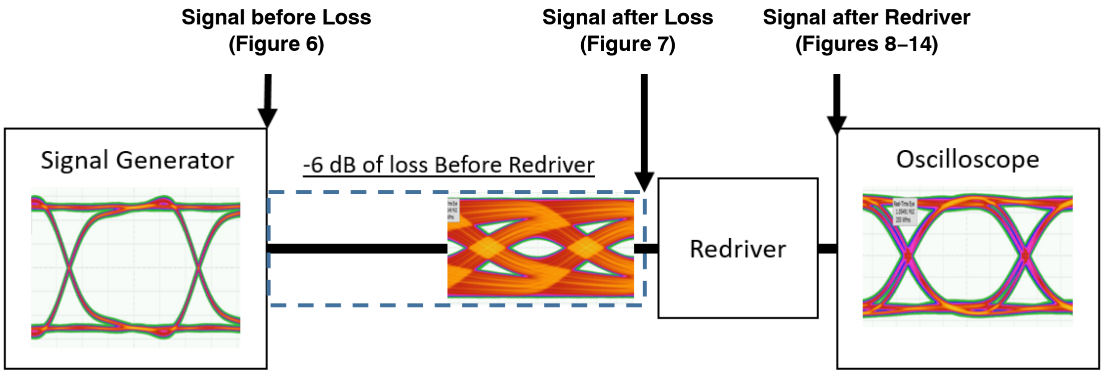

Figure 5. Block Diagram and Location of Signals

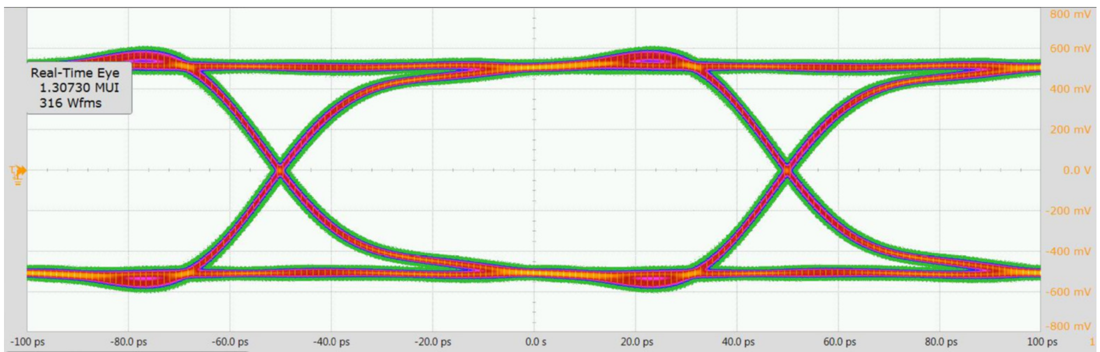

Figure 6. Eye Diagram of Signal before Loss

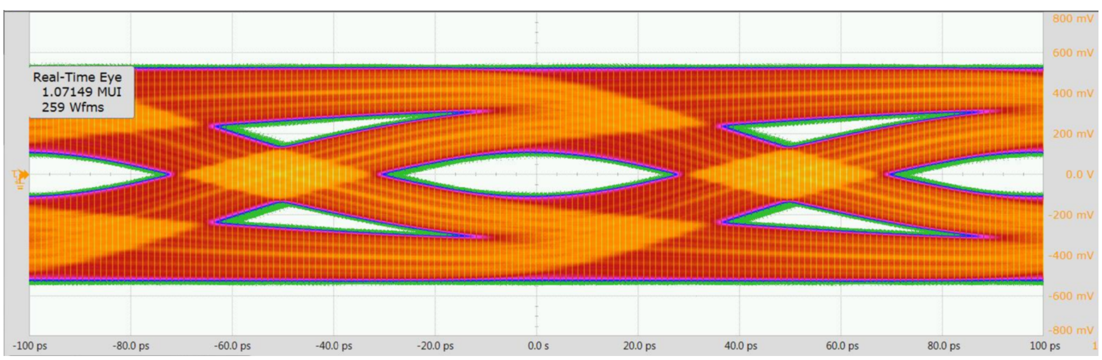

Figure 7. Eye Diagram of Signal after Loss

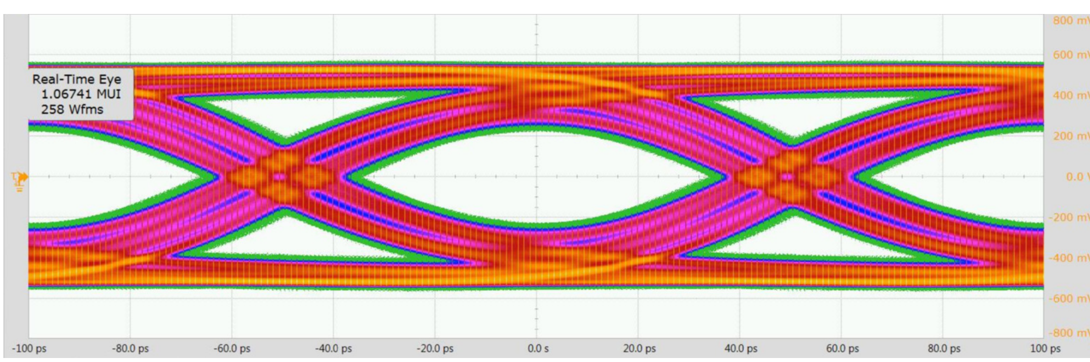

Figure 8. Eye Diagram Using Too Low of Equalization

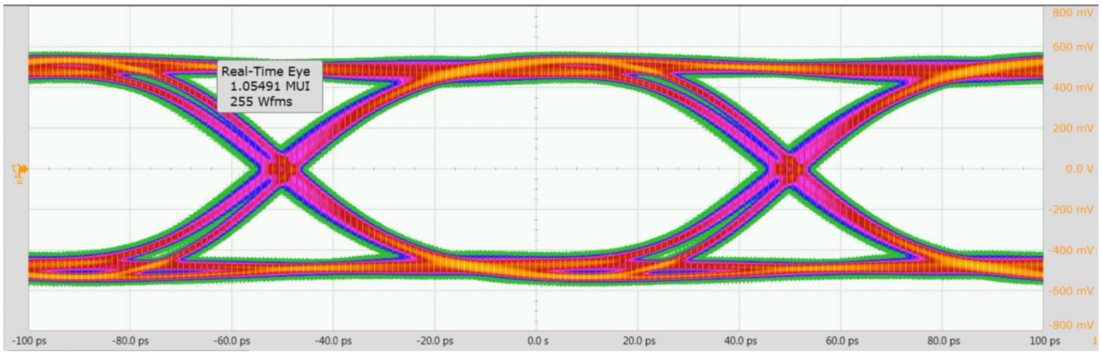

Figure 9. Eye Diagram Using Correct Equalization

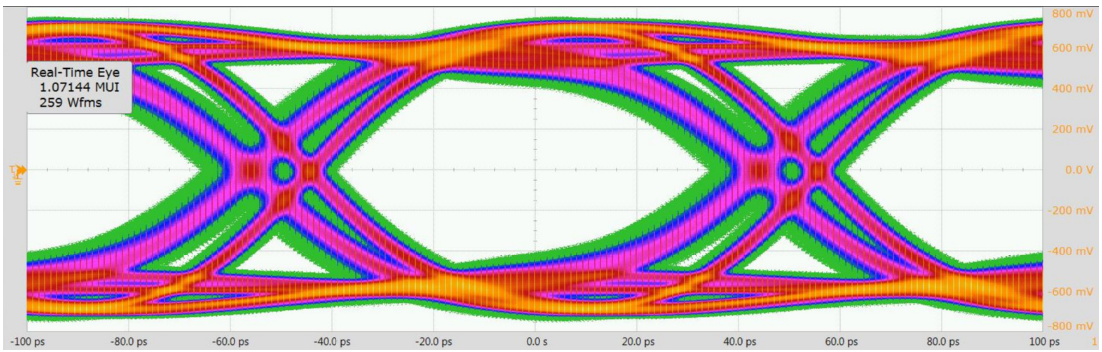

Figure 10. Eye Diagram Using Too Much Equalization

When selecting the equalization value on a redriver it is possible to not have enough equalization, and it is also possible to use excessive equalization. When an equalization setting that is too high for the loss is chosen it is called over equalizing the signal. This situation should be avoided, because the over equalization can cause signal distortion that may cause jitter, see Figure 10.

Tuning Flat Gain

Standards like USB also have electrical amplitude requirement to be compliant and function properly. In many cases the host transmitters cannot or do not provide the correct output amplitude. To meet this, redrivers offer selectable flat gains. The flat gain can be increased or decreased depending on the systems amplitude necessity. Flat gain adjustments are often required to meet the USB 3.1 low frequency link training amplitude range of 800−1200 mV. Some hosts may provide under 800 mV of amplitude, these systems would need to use the redriver positive flat gain settings. For hosts that exceed 1200 mV, the redriver negative flat gain settings would need to be used to reduce the amplitude. Figures 11−13, respectively, demonstrate a negative flat gain adjustment, the zero flat gain adjustment, and positive flat gain adjustment of a redriver.

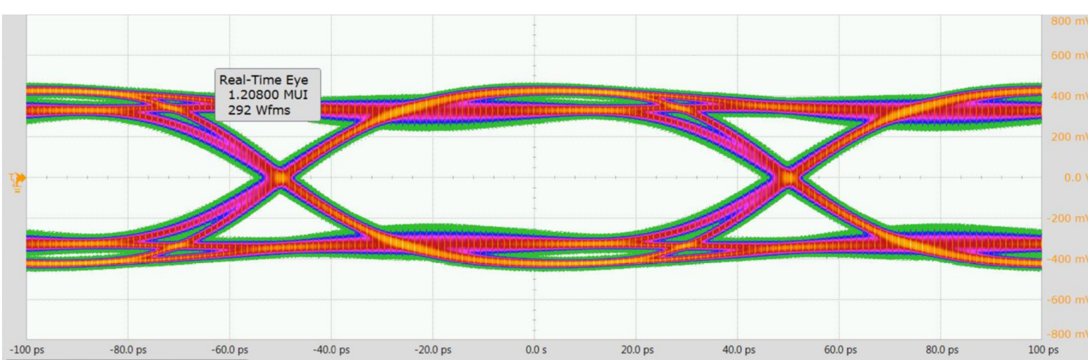

Figure 11. Eye Diagram Using Negative Flat Gain

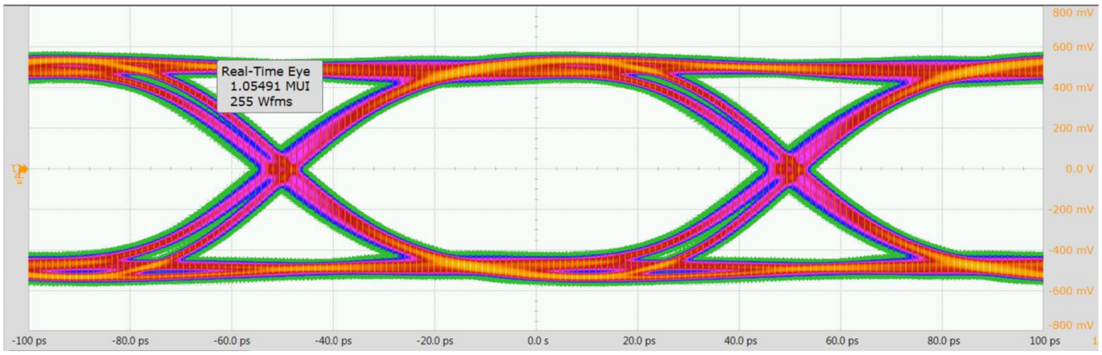

Figure 12. Eye Diagram Using No Flat Gain

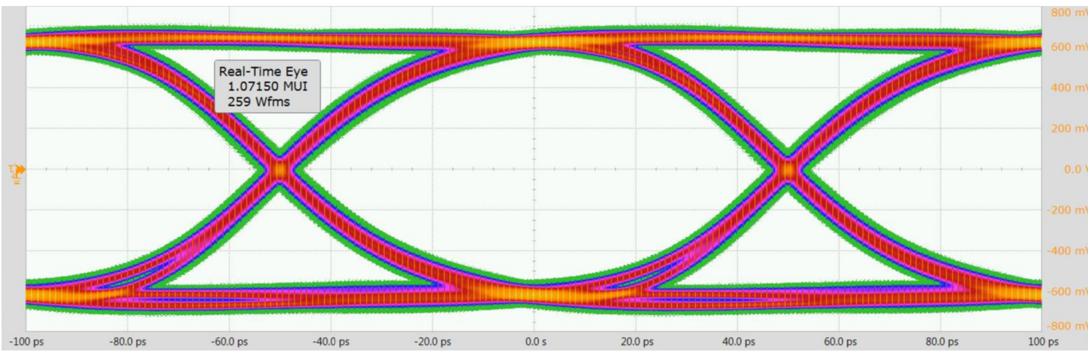

Figure 13. Eye Diagram Using Positive Flat Gain

Tuning Output Compression

Some redrivers offer selectable output compression. It is the electrical amplitude limitation of a redrivers output and can be used to limit the transmitters output swing. If an input signal drives the output far beyond the compression point, the output may become distorted, see Figure 14. This is because the signal is no longer in the linear region and being limited.

When selecting the output compression for a redriver, it should be set to the adequate output required by the application. Using USB as the example again, the compression for redrivers is normally set to its nominal output of 1000 mV to 1200 mV. In some cases compression may be a useful tool to limit the redriver output if the input amplitude is slightly too high. In some USB systems the redrivers use compression of 1000 mV to limit the low frequency link training amplitude.

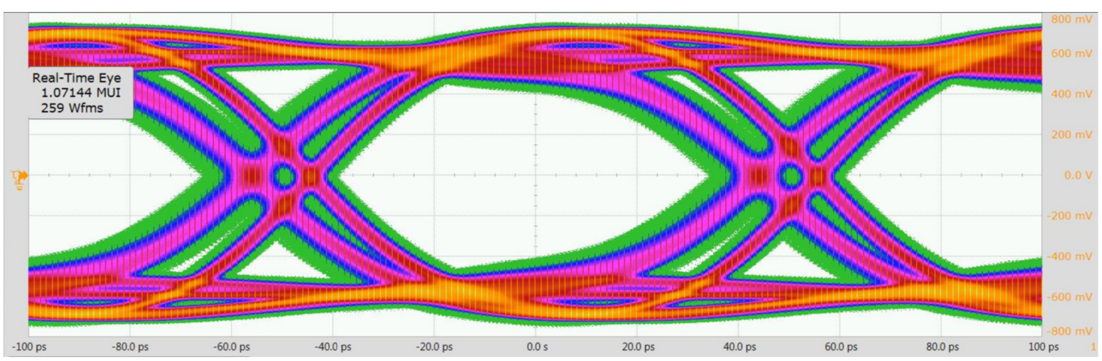

Figure 14. Eye Diagram with Distortion from Driving Signal Past Compression Point

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