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MAX3274 Optimizes Dual-Rate, Fibre Channel Receivers

MAXIM High-Frequency/Fiber Communications Group

Maxim Integrated Products

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1 Introduction

This discussion explores the need to suppress the relaxation oscillation of older Fibre Channel, 1Gbps transmitters and demonstrates the effectiveness of a new solution for dual-rate, Fibre Channel optical systems.

2 The Problem

With the establishment of 2Gbps Fibre Channel optical systems has come an interesting development in interoperability. In order to appease the demands of those who invested heavily in 1Gbps Fibre Channel storage systems and fabric switching, dual-rate systems have been developed to allow the 1G and 2G equipment to coexist in the same network. A very elaborate and comprehensive technique was developed by the T11 organization to solve the software issues associated with negotiating a common data rate to allow the old to communicate with the new. In addition, a new optical transceiver interface was specified that has a hardware pin designation for "rate select." See Figure 1. It is defined as a receiver-bandwidth control, but, until now, nothing practical has been available to implement it.

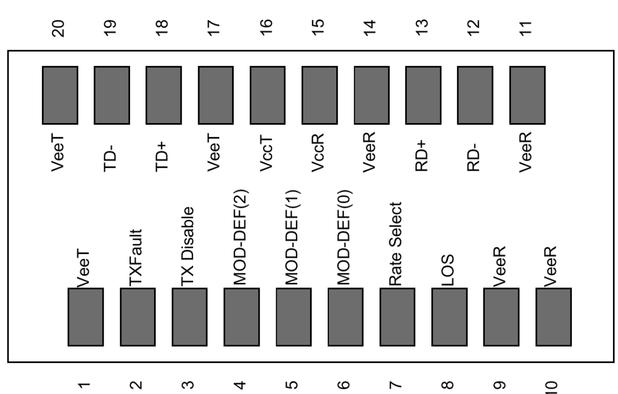

Figure 1. Pin assignments for a Fibre Channel optical transceiver as given by the Multi-Source Agreement for Small Form-factor Pluggable (SFP) modules. Pin 7 is Rate Select.

The consumers of the optical transceiver modules demand that the quality of performance of their older systems be maintained, while adding the new capabilities and speed of the newer systems. In other words, they demand "backward compatibility." An examination of the physical layer characteristics of the old link is essential to understand how one critical component of performance will be affected. This is receiver sensitivity, which is simply the lowest optical power level or modulation amplitude at which the bit-error rate remains below acceptable limits. In this application, this limit is one error out of 10^{12} bits or a ratio of 10^{-12} .

To appreciate the difficulties of a dual-rate system at the physical layer, legacy optical transmitters must be considered.

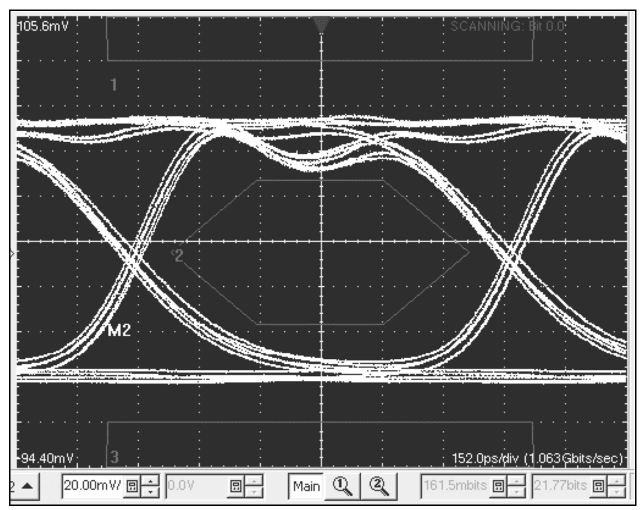

*Figure 2. The transmit eye of an older 1G Fibre Channel GBIC with a CD-laser as viewed with an 800MHz (0.75*bit rate) reference receiver.*

Figure 2 is an example of what was shipped in the early days of 1Gbps Fibre Channel GBICs, GLMs and "9-pin" optical transceiver modules. These early units used Fabry-Perot lasers intended for compact disk players. This sample passes the 1G transmitter mask test, but with little margin.

There are a lot of 1G transmitters out there like this one. Together with an optical receiver of the same 1G family, where the bandwidth is 800MHz or less, the link performs well. What happens in a 2G system?

An examination of the eye opening of Figure 2 shows undershoot at the logic-one level. At first glance this might be mistaken for an impedance mismatch or improper bandwidth characteristic, but the lack of symmetry with the logic-zero portion of the eye suggests a different problem. Experienced designers of optical transmitters will recognize this at once as the remnant of relaxation oscillation. Figure 3 shows the same laser transmitter when viewed with a 1.9GHz bandwidth (–3dB electrical) optical-to-electrical converter.

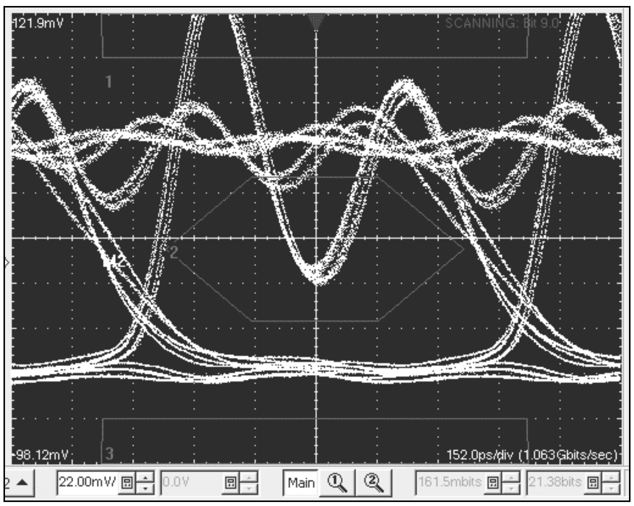

Figure 3. Another view of the same GBIC transmitter. When viewed with 1.9GHz bandwidth, the severity of relaxation oscillation in the older GBIC becomes apparent.

A receiver designer might be horrified by the prospect of passing this along to the next stage in someone's circuit. The bandwidth of the 2G receiver could be reduced to suppress relaxation oscillation while maintaining functionality of the 2G link. Doing this will compromise sensitivity for both rates. Figure 4 shows the result of further bandwidth reduction to 1.2GHz (-3dB electrical). With the logic-one undershoot well above the vertical center, a limiting amplifier will produce an open eye as long as the optical power is maintained well above the linear region of the limiting amplifier.

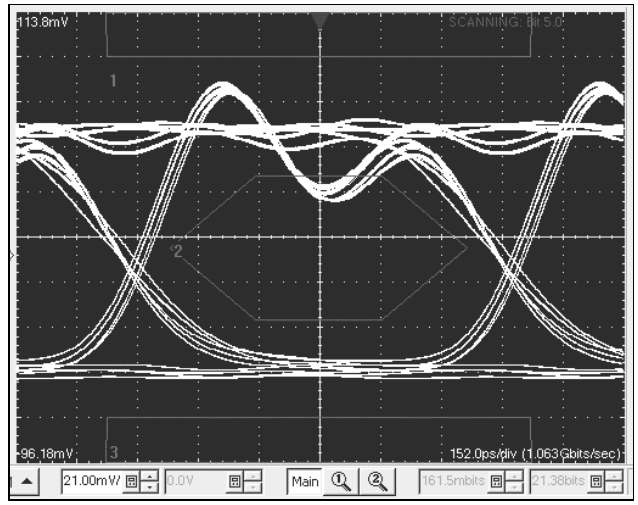

Figure 4. Reducing the receiver bandwidth to 1.2GHz provides some control over the relaxation oscillation; however, it compromises operation at the 2G rate.

In Figure 5, the output of the limiting amplifier with such a compromised bandwidth shows the effect of operating at low power levels previously acceptable for a 1G link. The undershoot is no longer being swept into the logic-one limit and the eye is closing.

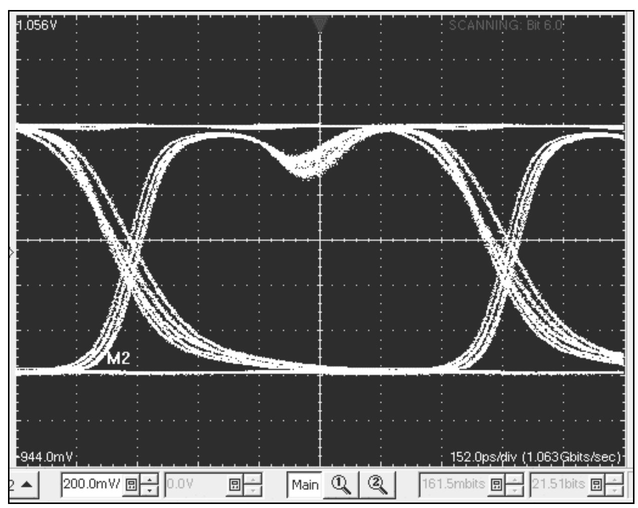

Figure 5. Limiting amplifier output. At the minimum optical power for the link, the receiver is operating near or at its linear region. Even with reduced receiver bandwidth, the undershoot of the relaxation oscillation escapes limiting and threatens to close the eye.

The bit-error rate (BER) at the output of the limiting amplifier in Figure 5 was checked. The vertical level at which the logic-one errors exceeded 10^{-12} was measured differential at 130mV. This violates the 185mV minimum eye-opening requirement for the Fibre Channel interoperability receive point δ_R (delta-R). This link cannot meet the older 1G link sensitivity.

3 The Solution

The solution is to not compromise the bandwidth, but rather to optimize it! The MAX3274 Dual-Rate Limiting Amplifier is equipped with a selectable 4^{th} Order Bessel-Thompson filter. Figure 6 shows the block diagram. By setting the BWSEL pin to a TTL low level, the input signal is routed through the filter section. The –3dB response of the filter is approximately 900MHz, but more importantly the loss at 2GHz is greater than 15dB. This is more than enough to fully suppress the relaxation oscillation that is typically 2.5GHz to 3GHz in the older transmitters. Figure 7 shows the output of the MAX3274 with BWSEL = 0 for the same optical conditions as in Figure 5. The resulting eye in Figure 7 is completely free of the undershoot, allowing for optimum link performance. The MAX3274 limiting amplifier output was also checked for BER. The vertical level at which the logic-one errors exceeded 10^{-12} was measured differential at approximately 360mV. This is well above the 185mV minimum eye-opening requirement at δ_R (delta-R). It is nearly two times the required level. This translates as an increase in sensitivity of nearly 3dB of optical power for the 1G link.

4 Conclusion

Using the MAX3274, the bandwidth of dual-rate, Fibre Channel links can be optimized for each of the two data rates. There is no longer any reason to compromise the performance of either link. Now the promise of upgrading to a new and improved dual-rate Fibre Channel system can be fulfilled without any strings or penalties; finally, there is something to do with that "rate select" pin!

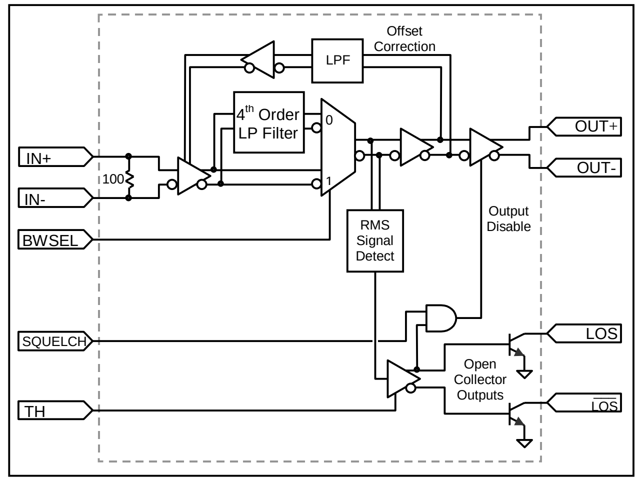

Figure 6. Block diagram of the MAX3274, Dual-Rate Limiting Amplifier. The selectable filter allows for suppression of the relaxation oscillation in older 1G Fibre Channel links.

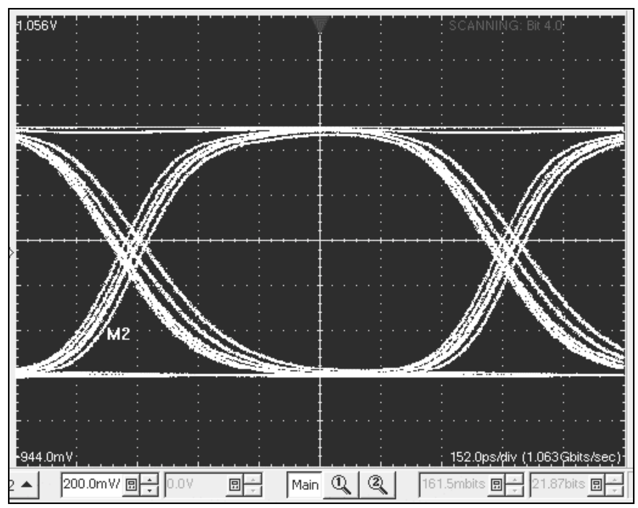

Figure 7. The MAX3274 output with the BWSEL set to enable the built-in 4^{th} Order Bessel-Thompson filter. The eye is open while the optical power is at the minimum and the relaxation oscillation is suppressed.

(NOTE: The eye diagrams shown in this document were acquired using the Tektronix CSA8000 and a K28.5± pattern. The FrameScan® feature of the CSA8000 was used to reduce random jitter so that the deterministic features could be viewed directly.)