

Design Note:

**HFDN-26.2**

Rev 0; 09/03

---

---

**MAX3735A Laser Driver Output Configurations,  
Part 3: Differential Drive**

---

---

MAXIM High-Frequency/Fiber Communications Group



Maxim Integrated Products



# MAX3735A Output Configurations, Part3: Differential Drive

## 1 Introduction

The MAX3735A is a DC-coupled SFP laser driver designed for data rates up to 2.7Gbps (reference [1](#)). The multi-rate capability, small package, APC loop, SFP safety/timing specifications and monitor outputs of the MAX3735A make it suitable for a large variety of optical module applications operating over a wide range of data rates. The output of the MAX3735A is intended to drive DC-coupled, edge-emitting, common-anode lasers, but it can also be used to drive a variety of other laser configurations (reference [2](#)).

This design note (Part 3 of a series of notes) will discuss the differential drive interface in detail. The purpose of this application note and others in the series is to examine the advantages and disadvantages of the various output configurations, and to provide schematics and examples that will help module designers choose the optimal output structure for their application.

The MAX3735A will be used as an example to discuss these interfaces, but the techniques can be applied to other laser drivers such as the MAX3737, MAX3735, MAX3850 and MAX3656, due to their similar output structures.

## 2 Differential Drive

Differentially driving a laser can provide significant improvements to the optical performance and also improve EMI radiation. However, there are also some drawbacks to the differential drive that should be considered which may or may not affect the overall system performance.

### 2.1 Differential Drive Advantages

1. **Improved Edge Speeds** – The differential drive provides an active switching of the current on and off through the laser. Standard AC-coupled interfaces and DC-coupled interfaces can only actively turn the

laser on. The laser's properties and parasitic capacitance therefore limit the turn-off time of these configurations. The differential drive can improve the falling edge because it actively turns the laser off. This benefit is demonstrated in Figure 1 and Figure 2.

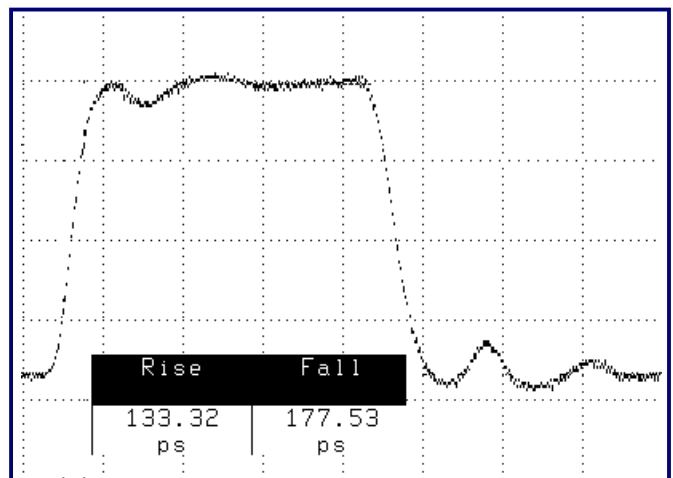


Figure 1. Optical Rise and Fall Times With DC Coupled Output.

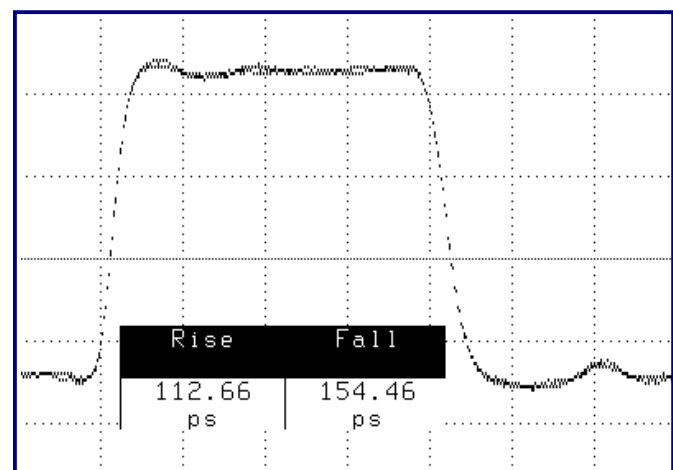


Figure 2. Optical Rise and Fall Times With Differential Output and Same Laser as Figure 1.

2. **Improved Current Flow** – The differential-drive structure provides a closed current loop that can improve overall performance for some lasers and reduce EMI emission. See Figure 3 and Figure 4.

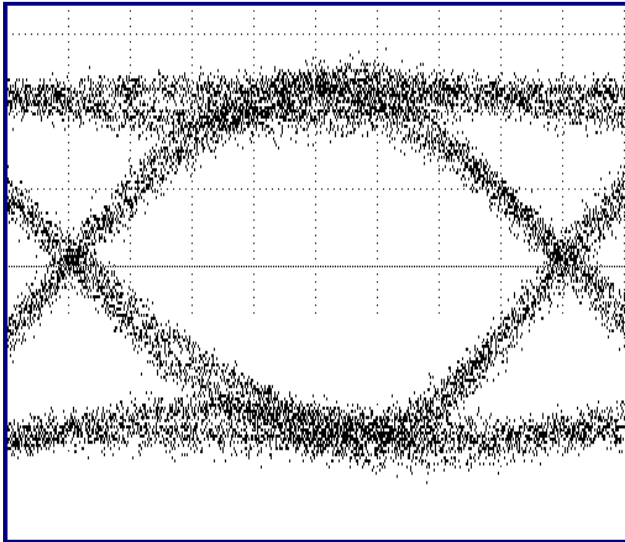


Figure 3. OC48 Optical Eye Diagram (DC Coupled)

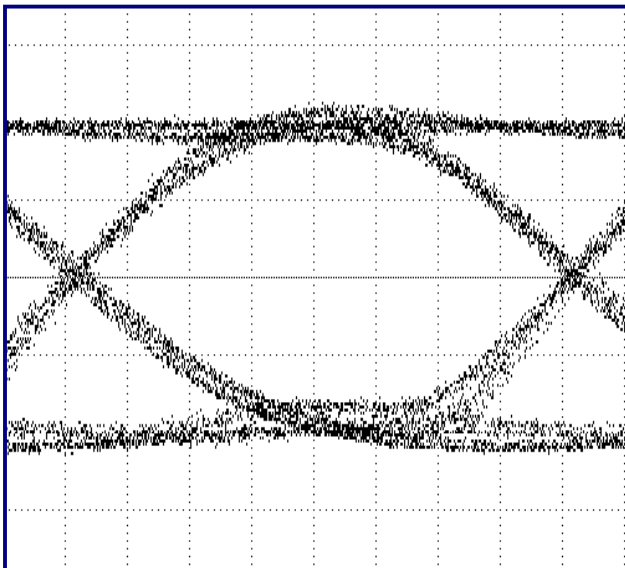


Figure 4. OC48 Optical Eye Diagram (Differential, Same Laser as Figure 3.)

3. **Increase Tolerance of Inductance** – The AC-coupling capacitor in the modulation path isolates the forward voltage of the laser from the driver outputs. This increases the headroom available for the laser modulation and makes the output more tolerant of inductance in the signal path.

## 2.2 Differential Drive Disadvantages

1. **Low Frequency Cutoff** – The differential drive structure must be AC coupled. The AC coupling introduces a low-frequency cut-off that will affect performance at low data rates when using long patterns due to baseline wander (Reference 4). See section 4.1 *Baseline Wander / Component Selection* for more detail.
2. **Laser Pin Out** – For best performance, the laser anode and cathode should be isolated from the monitor diode and the case. See section 4.2.2 *Laser Pin-Out* for more detail.
3. **Components** – More external components are required in a differential-drive configuration than in a DC-coupled configuration. Generally 2 to 5 more components are necessary than what is needed for a DC-coupled interface.
4. **Power Consumption** – The power consumption for differential drives is larger than DC-coupled outputs due to the increased bias current required for AC-coupled output. When DC coupled, the modulation current contributes to the average optical power. Therefore, AC-coupled interfaces require approximately  $(I_{MOD} / 2)$  more current to operate than a DC-coupled output.

## 3 Differential Drive Configurations

There are many ways to configure a differential drive output. Most of these methods can be divided into two main groups: Inductive Pull-Ups and Resistive Pull-Ups.

### 3.1 Inductive Pull-Up Method

Figure 5 illustrates the basic connections of an inductive pull-up differential-drive configuration. The diagram also illustrates the current flow for a logic one and a logic zero. Since the forward voltage of the laser is isolated from the OUT+ pin, up to 80mA of modulation current can be obtained when using the MAX3735.

The pull-ups (inductors connected to  $V_{CC}$ ) can be accomplished with inductors or ferrite beads or a combination of the two. The components that connect directly to the OUT pins should have small DC impedance and large impedance in the MHz to GHz range. Ferrite beads (such as TDK MMZ1608A152ET and Murata BLM18HG601SN) work well in these locations. Additional series inductance and a shunt network may also be added to improve the performance (See section 4 for more information).

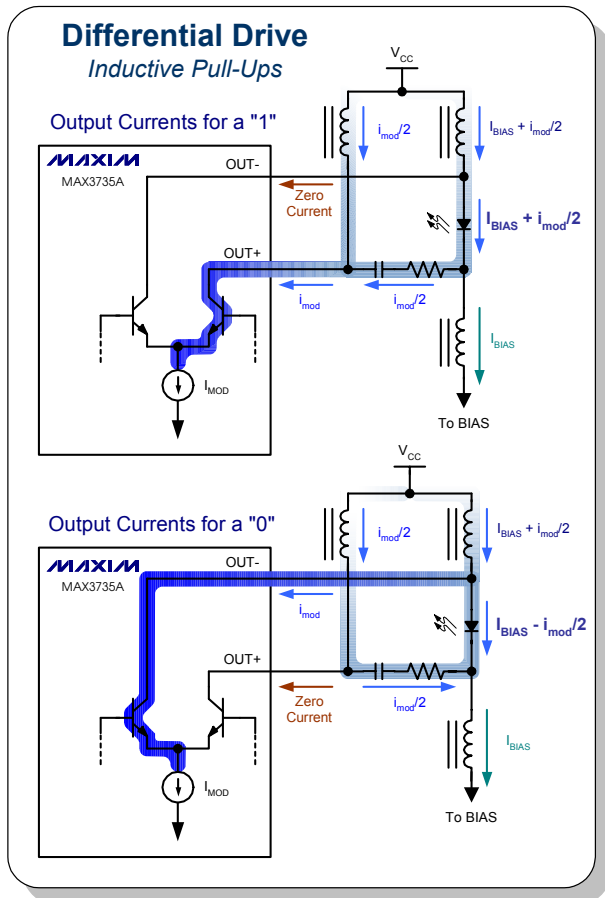


Figure 5. Differential Drive (Inductive Pull-Ups)

### 3.2 Resistor Pull-Up Method

The resistor pull-up method (Figure 6) is very similar to the inductive pull-up method except that the pull-up on the OUT pins is done with resistors. This method provides back termination and requires fewer inductors, but the total modulation current that is delivered to the laser is reduced. Assuming a  $6\Omega$  laser and the components shown in Figure 6, the

attainable modulation current is approximately 70mA.

The selection of the inductor on the laser anode to  $V_{CC}$  is the same as for the inductive pull-up (ferrite bead, inductor or combination). As with the other method, additional series inductance and a shunt network may also be added to improve the performance (See section 4 for more information).

Variations of each of these methods are possible. For example, the series resistor with the resistive pull-up method is optional and an additional AC-coupling capacitor can be added between the resistor and bead on the OUT- connection. The exact components and values will vary with board layout and the impedance of the laser that is used. An example is illustrated in section 5 using a variation of the resistive pull-up method.

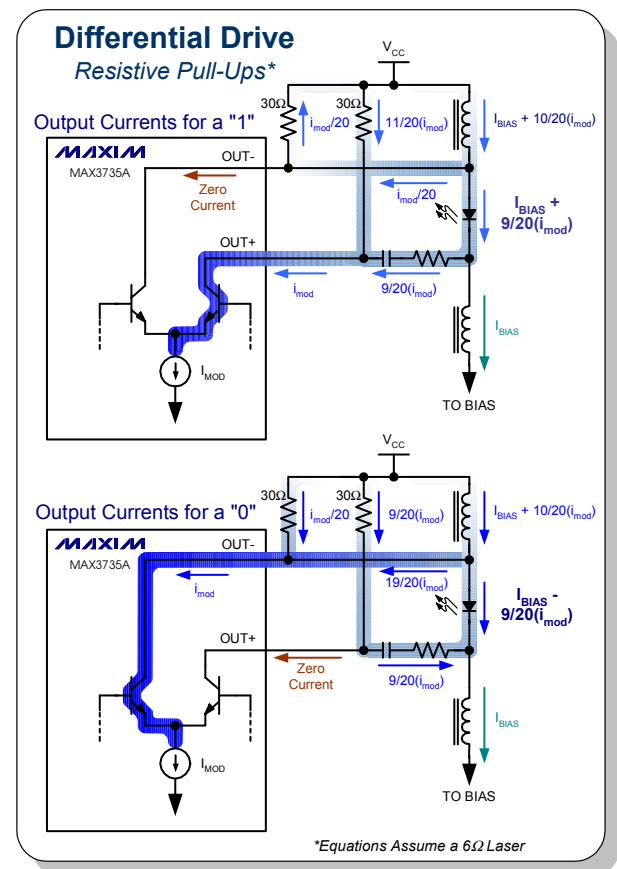


Figure 6. Differential Drive (Resistive Pull-Ups).

## 4 Special Considerations / Layout Techniques

To obtain good results at high or multiple data rates, variables such as the baseline wander, component values/placement, laser package, return path and filtering should be carefully evaluated. A matching network may also be needed to reduce overshoot and ringing.

### 4.1 Baseline Wander / Component Selection

The AC-coupled output of the differential drive configuration requires special attention to be paid to the operational data rates and the possible baseline wander effects (Reference 4). For differential drive outputs, both the AC coupling capacitor size and the pull-up inductance should be carefully chosen when operating at multiple data rates.

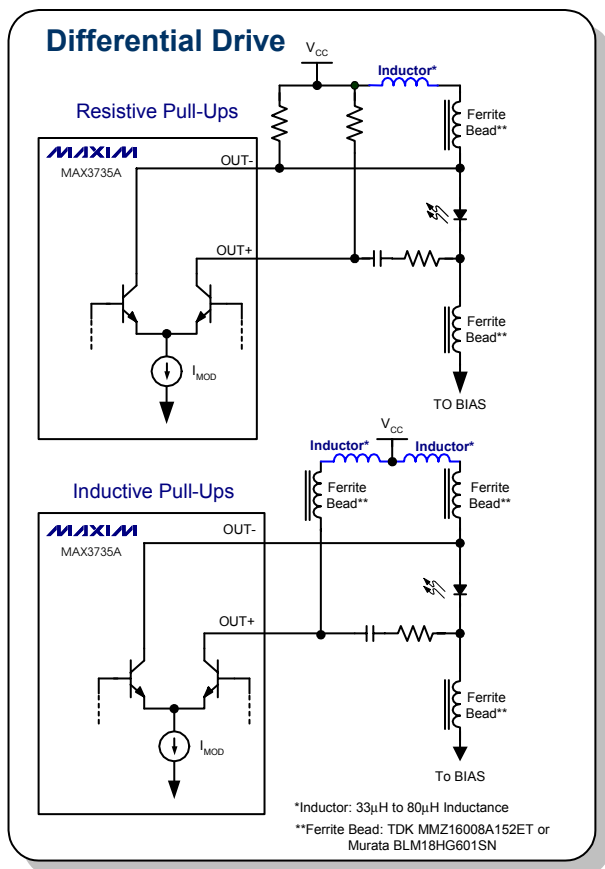


Figure 7. Additional Inductance

The AC-coupling and pull-up inductors on the output introduce a low-frequency cut-off that will affect operation when using patterns or data rates

with low-frequency content. Ferrite beads (such as TDK MMZ1608A152ET or Murata BLM18HG601SN) and a reasonable size AC-coupling capacitor (0.047 to .1µF) work well for high data rate applications. If operating at data rates below 1Gbps (for scrambled data) or 100Mbps (for 8b/10b or similarly coded data), the capacitor value should be increased and a large inductor should be added in series (Figure 7) with each ferrite bead that connects to  $V_{CC}$ . The additional inductance and capacitance lowers the low-frequency cut-off point which will reduce baseline wander and improve the overall performance at lower data rates. See references 5 and 6 for more information about calculating the low-frequency cut-off point and the required capacitance / inductance when operating at lower data rates.

Operation at data rates below 155Mbps (scrambled data) or 10Mbps (8b/10b data) is generally not practical for differential drive outputs due to the low-frequency cut-off points of the AC coupling. Below these data rates, the inductors' and capacitors' physical size, which is related to their capacitance and inductance, becomes unreasonably large.

### 4.2 Laser Package and Connections

The inductance and capacitance in the modulation path should be reduced as much as possible when modulating laser diodes at gigabit data rates. Parasitic inductance and capacitance of the laser and external components will decrease edge speeds, which can lead to increased jitter. Care should be taken to minimize the parasitic inductance and capacitance for all the components in the output signal path, which include the laser package and its internal and external connections.

Using short connections from the laser driver to the laser, short leads (for a TO style package) or improved laser packages will reduce the series inductance. When possible, a TO-style laser should be edge mounted to eliminate the parasitic affects of the through-hole connections.

#### 4.2.1 Edge Mounting the Laser

It is common in circuit board design to pull the ground and power plane back from the physical edge of the board. But, when connecting a TO-style laser to the edge of the board, the ground plane should extend to the edge of the board that interfaces with the laser (Figure 8). Extending the ground plane will

reduce the inductance of the leads and improve the high-speed performance. If possible, the high-speed connections (laser anode and cathode) should be placed on the top of the circuit board to take advantage of the lower lead inductance created by the extended ground plane. The laser should also be mounted as close as possible to the edge of the board to reduce the inductance of the leads.

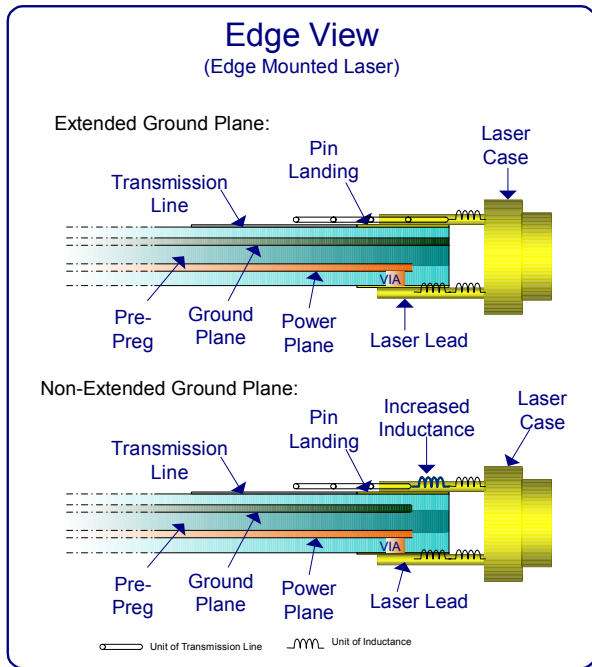


Figure 8. Edge Mounting a Laser

#### 4.2.2 Laser Pin-Out

The pin-out and construction of the laser can have a large affect on the overall performance when using a differential-drive output. Ideally, the laser anode and cathode should be isolated from the case and the photodiode when using a differential-drive structure (Configuration #1, Figure 9). The other configurations can also work, but performance will vary depending on the construction of the laser and should be carefully evaluated. When the case or the photodiode are connected to the laser anode, there are additional parasitic elements that will affect the high-speed performance.

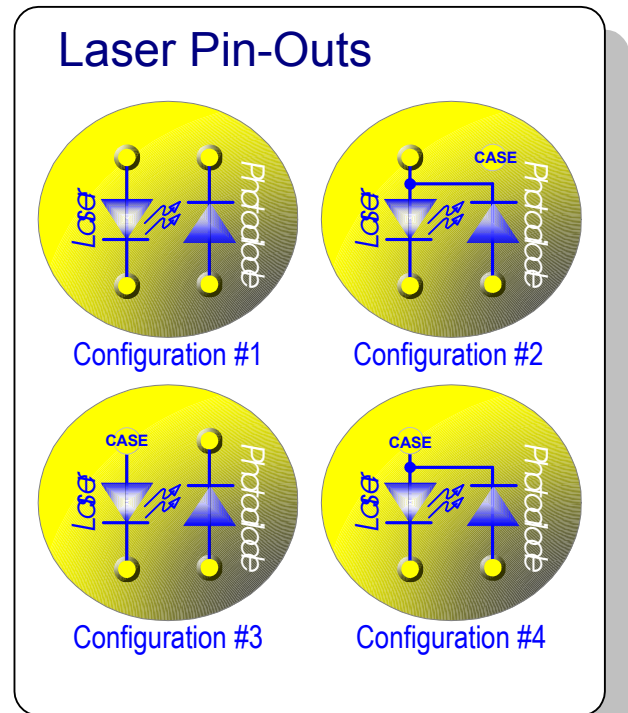


Figure 9. Laser Pin-Outs

### 4.3 Component Placement, Return Path and Bypassing

Creating transmission lines to match a low-impedance differential load can be difficult. By placing the laser close to the driver, transmission lines geometries can be neglected as long as the length of the connection is small compared to the wavelength that is expected to propagate down the line. For FR-4 material and the data rates being used (2.5Gbps), this length should be less than about 6 or 7mm. If the distance is small compared to the wavelength, the trace width can then be reduced which will lower the parasitic capacitance on the output.

Using Figure 12 as a reference, a possible component placement is shown in Figure 10. (Note: These configurations are suggestions only and should be evaluated and modified as necessary for each application.)

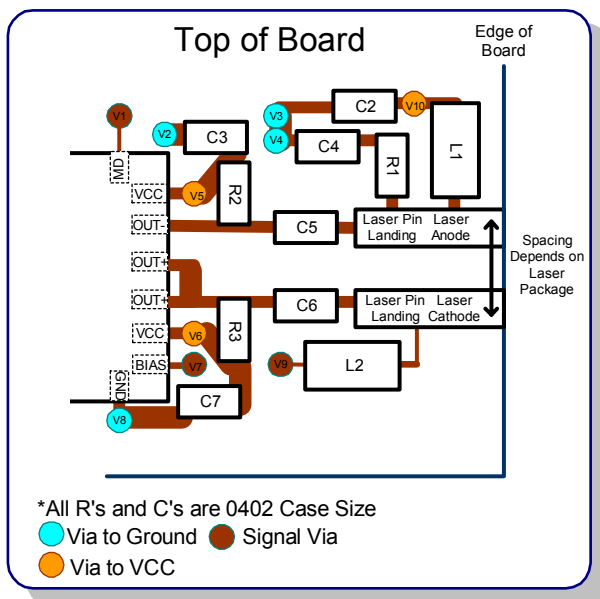


Figure 10. Possible Component Placement

An important part of component placement is in evaluating the return path, current flow and filtering. Dedicated ground and power planes should be used. Using dedicated planes will lower the connection impedance and provide a better return path for the high-speed currents. The return path of the bypass capacitors should also be oriented (if possible) so the ground connection is close to the transmission line and the ground of the device.

For differential-drive outputs, both outputs and laser leads connecting to the laser should be placed on the same side of the PCB (Figure 10). By placing both connections on top of the PCB, the return path is shortened and vias are eliminated from the signal paths.

When using resistive pull-ups, both of the pull-up resistors will have small amounts of high-speed switching current. The resistors should therefore be terminated to  $V_{CC}$  with short connections and also be well bypassed. When possible, both resistors should be terminated to the same physical location on the PCB.

#### 4.4 Matching Networks

When modulating lasers at gigabit data rates, a matching network is often needed to reduce ringing and overshoot on the output. Figure 11 illustrates some of the locations/methods that can be used. The exact values of the components should be determined experimentally, but will often range

from 0.5pF to 10pF for the capacitor and 30Ω to 75Ω for the resistor.

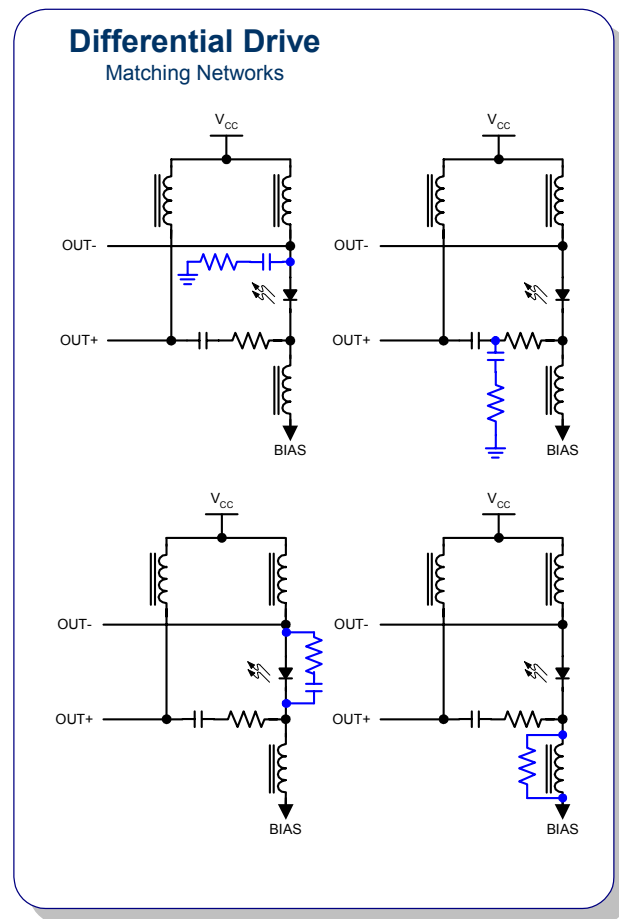


Figure 11. Matching Networks

The network should be optimized while finding a balance between overshoot and rise/fall times. Increasing the capacitance or decreasing the resistance will reduce the overshoot and slow down the edge speeds.

## 5 Example

### 5.1 Schematics

To illustrate the differential drive, a resistive divider network was built and tested with the MAX3735 and an edge-emitting laser (NX7315, Reference 7). The schematic connections can be seen in Figure 12. Capacitor C5 was added to match the DC level of the differential pair but is not necessary and can be replaced with a short or series resistor as part of the optimization process.

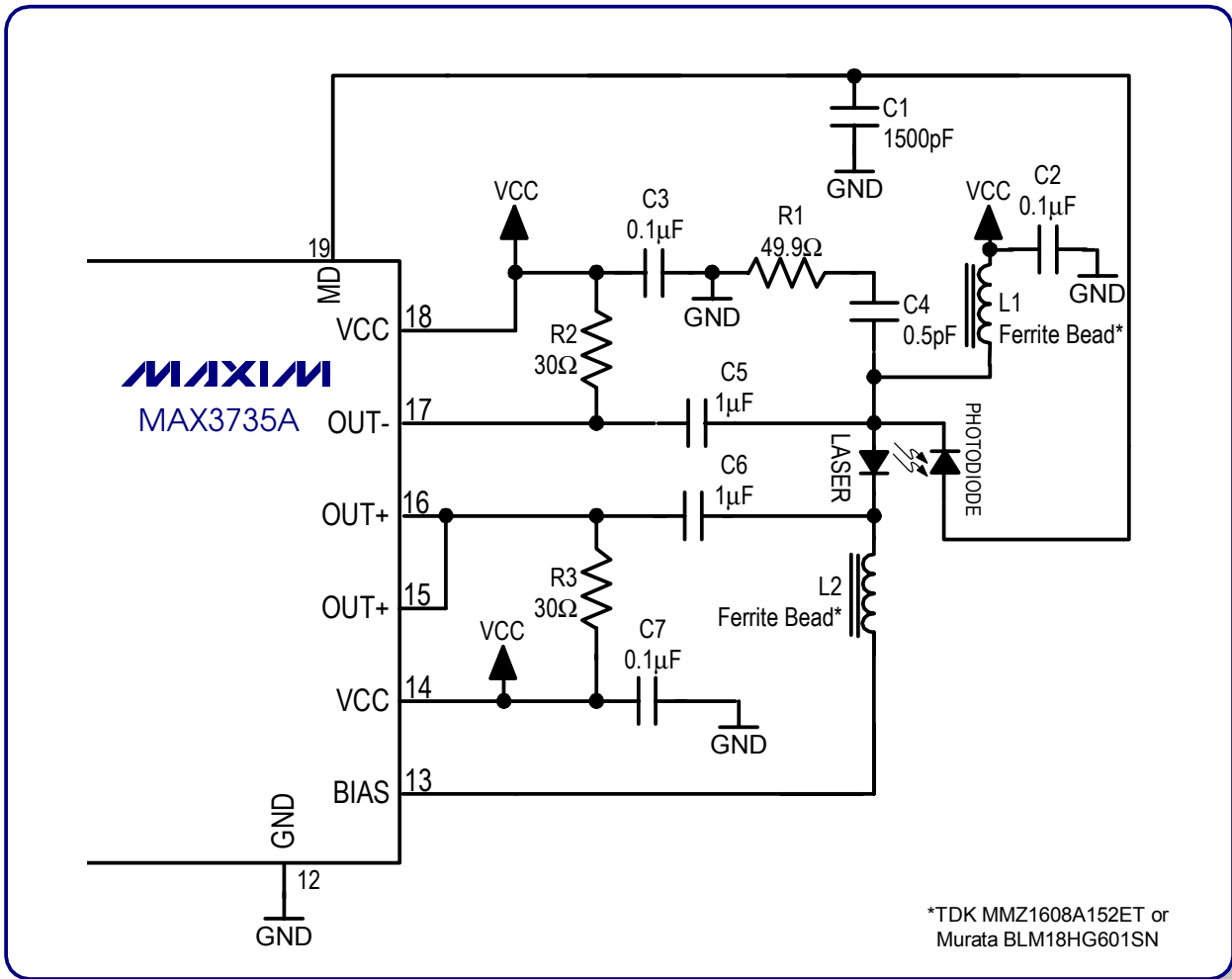


Figure 12. Schematic of output structure.



## 5.2 Test Data

Applying the suggestions above and the schematic shown in Figure 12, the following optical eye diagrams were obtained. Operation below 622Mbps (using long PRBS test patterns) is not recommended due to baseline wander affects. By adding series inductance (>33uH) between L1 and V<sub>CC</sub>, the baseline wander will be reduced. C5 and C6 can be reduced if operating only at data rates above 622Mbps.

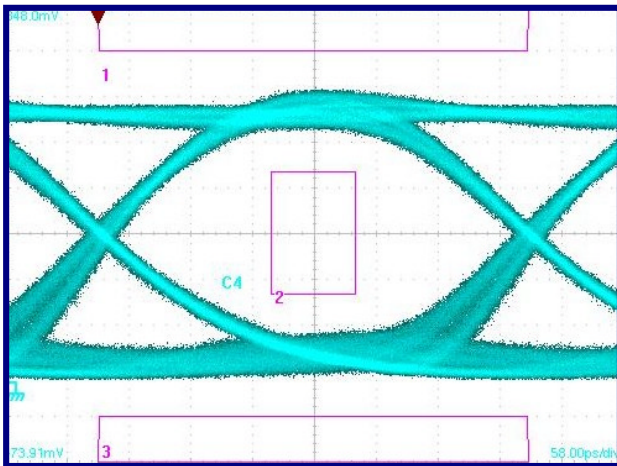


Figure 13. OC48 (Filtered),  $E_R = 9.7\text{dB}$ ,  $2^{23}-1$  PRBS,  $\approx 28\%$  Margin to Standard Mask

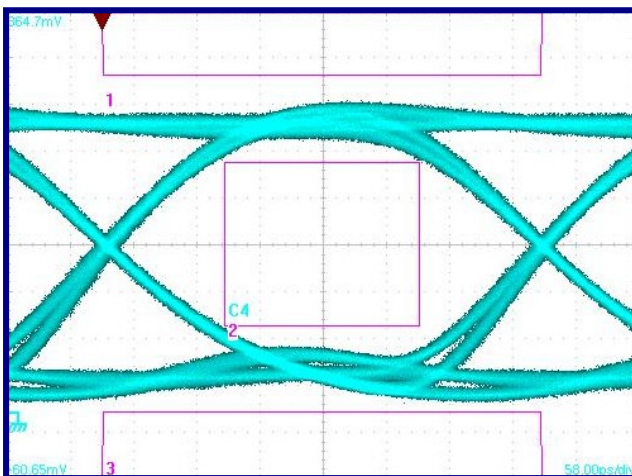


Figure 14. OC48 (Filtered),  $E_R = 8.4\text{dB}$ ,  $2^7-1$  PRBS, Shown with added 31% Margin to Standard Mask

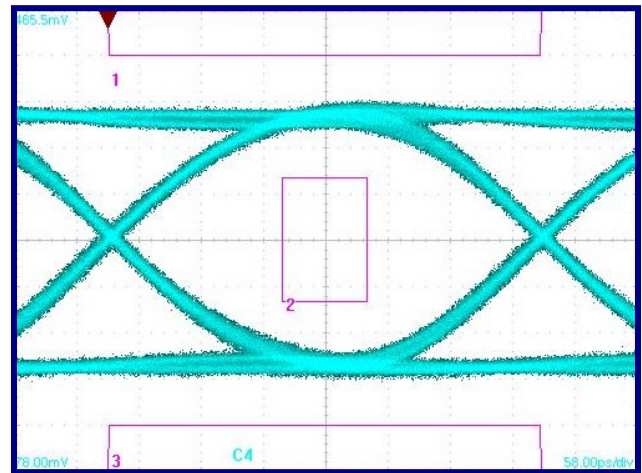


Figure 15. OC48 (Filtered), High Bias Current

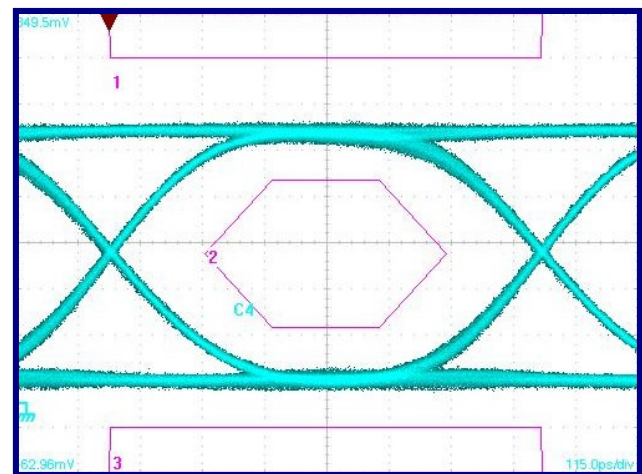


Figure 16. 1.25Gbps (Filtered),  $E_R = 10.4\text{dB}$ ,  $2^{23}-1$  PRBS,  $\approx 39\%$  Margin to Standard Mask

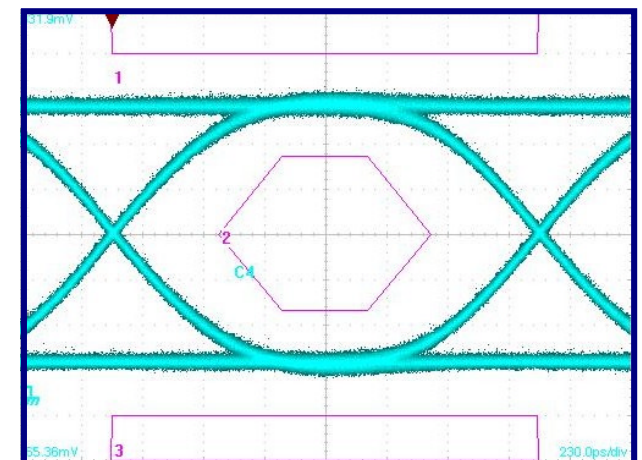


Figure 17. OC12 (Filtered),  $E_R = 10.7\text{dB}$ ,  $2^{23}-1$  PRBS

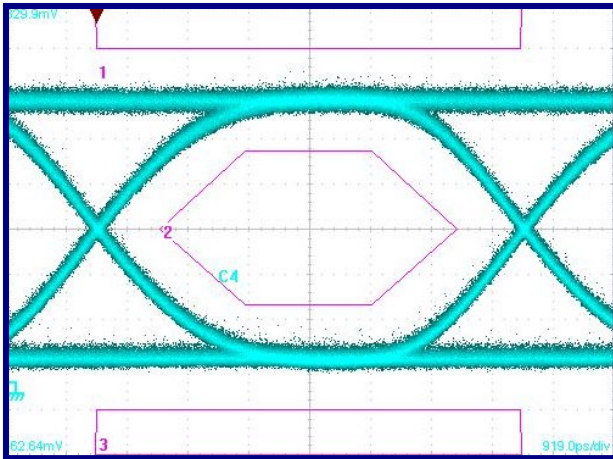


Figure 18. OC3 (Filtered),  $2^{23}$ -1PRBS

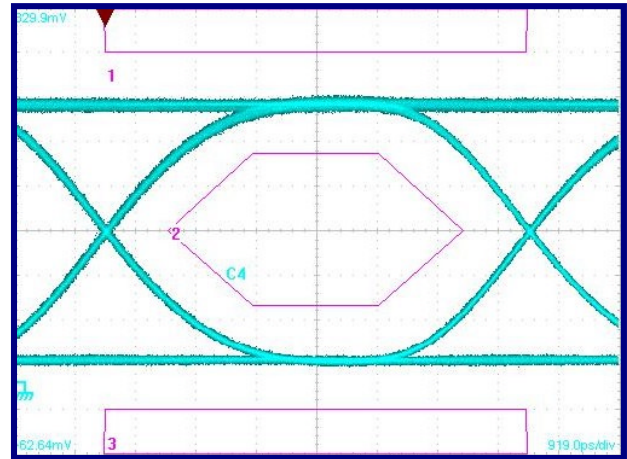


Figure 19. OC3 (Filtered),  $2^7$ -1PRBS

## 6 Conclusion

The differential drive optical interface of the MAX3735A can produce high-speed, high-performance eye diagrams by creating active switching of the laser for both the “on” and the “off” state. Various methods have been demonstrated and an example has been given that shows the performance.

## References:

1. Data Sheet: “MAX3735/MAX3735A: 2.7Gbps, Low Power SFP Laser Driver.” - [Maxim Integrated Products](#), May 2003.
2. Design Note: “[MAX3735A Output Configurations, Part 1: DC-Coupled Optimization Techniques](#)” - [HFDN-26.0](#), Maxim Integrated Products, June, 2003
3. Application Note: “[Interfacing Maxim Laser Drivers with Laser Diodes.](#)” - [HFAN-02.0](#), Maxim Integrated Products, May 2000.
4. Application Note: “[NRZ Bandwidth – LF Cutoff and Baseline Wander](#)” - [HFAN-09.0.4](#), Maxim Integrated Products, September 2002.
5. Application Note: “[Choosing AC-Coupling Capacitors.](#)” - [HFAN 01.1](#), Maxim Integrated Products, September 2000.
6. Data Sheet: “MAX3863 2.7Gbps Laser Driver with Modulation Compensation,” Page 9, - [Maxim Integrated Products](#), October 2002.
7. Preliminary Data Sheet “Laser Diode NX7315UA” – NEC, August 2002.