microbridge **WHITE PAPER**

Rejustor™ Based Optical Device Compensation

1 Introduction

The once dormant optical networking revolution is gaining momentum. Many laser-driver and optical receiver manufactures are looking for more effective adjustments that require less manual intervention and are suitable for high-volume production. Low-TCR *Rejustors* from Microbridge Technologies are a cost-effective solution for automating complex adjustments while optimizing performance for laser drivers and detectors without sacrificing performance.

Optical devices, such as laser diodes and photodetectors are biased to optimize responsivity (or sensitivity). Traditionally this is accomplished using a resistor to control current. *Rejustors* have demonstrated the ability to compensate analog problems in an analog domain. Low-TCR *Rejustors* from Microbridge Technologies provide the link between precision and flexibility and are suited for automated test and calibration – which reduces manufacturing cost and complexity.

There are three principal types of laser transmitters; Fabry-Perot (FP), Distributed Feedback (DFB) laser diodes and VCSELs (Vertical Cavity Surface Emitting Laser). These devices require a constant DC current to bias the transmitter. The optical output is then modulated around the bias point. The relative optical signal strength between a “1” and a “0” is dependant on the current which is set by a resistor. An analog problem with a *Rejustor*-based analog solution.

Optical receivers are typically PIN diodes or avalanche photo-diodes (APD). Like transmitters, these need to be biased to improve sensitivity – an adjustment usually made through time-consuming manual intervention.

Rejustors are ideal for Optical applications because they provide high-precision and behave as a resistor into the GHz range (unlike digital Pots that have high capacitance). Most importantly, *Rejustors* are re-adjustable. If the transmitter or receiver loses sensitivity with aging, the module could be re-trimmed to extend product life.

Rejustors are electrically adjustable micro-resistors. The resistance of *Rejustors* can be trimmed to very high-precision. The trimming process reversibly alters the material properties of the device and the trim is “stored” in the material indefinitely with no external power required. The resistance can be trimmed bi-directionally many times using low-power analog signals under control of Microbridge Technologies *Rejust-it* programmer or equivalent off-the-shelf hardware.

™ *Rejustor* is a trademark of Microbridge Technologies

2 Overview

Traditionally optical elements have been compensated using digital pots, laser-trimmed thick-film or hand-selected precision resistors. The *Rejustor* provides a simple approach to calibration and compensation in the analog domain that is suitable for automation. In fact, *Rejustors* can be used anywhere you need to adjust a resistor.

The key differentiation achieved using *Rejustor* based compensation is that optical devices can be calibrated after assembly (for example calibration after a protective lens is installed). Other precision trimming methods, such as, laser trimming, or hand-selected fixed resistors require an additional calibration step before final assembly – potentially reducing accuracy. Digital pots are plagued with the problem of compensating wiper resistance (in addition to limited operating bandwidth). It should be obvious that *Rejustors* are more effective and efficient in these applications without compromising precision.

A *Rejustor*-based optical transmission subassembly is discussed in Section 3. Two *Rejustor*-based optical receiver applications are presented in Section 4. The first uses a simple optical (photo diode) receiver configured in photoconductive mode, the second uses a Transimpedance amplifier combined with a photodetector in photovoltaic mode.

3 Optical Transmitters

Optical transmitters convert electrical signals to light using semiconductor devices, typically laser diodes, light-emitting diodes and VCSELs. In most cases a laser diode driver is required to bias the emitter to maximize the extinction ratio.

Figure 1 shows the typical operation of an optical emitter. The bias point on the response curve determines the extinction ratio, or optical difference between a “1” and a “0” as the current is modulated between the Current Modulation regions. Setting the bias point in the linear portion of the response curve not only enhances extinction ratio but gets the most optical change for a small change in current and also reduces jitter.

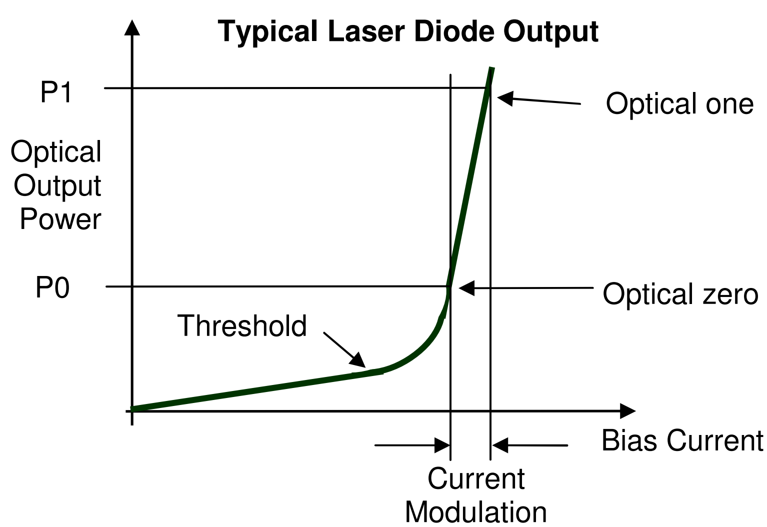

Figure 1: Typical Optical Diode Response

Bias-current is set by a laser-diode driver. There are many different types of laser-drivers, depending on the optics, the wavelength and transmit power. The bias current is regularly set with a precision resistor. This is where the *Rejustor* comes into the system.

3.1 Rejustor-Base Bias Current Control

The Maxim MAX3738[1], 155Mbps to 2.7Gbps SFF/SFP Laser Driver with Extinction Ratio Control, is designed for multi-rate transceiver applications. The bias current to the Laser is controlled by resistor R_{MODSET}. The MODSET pin has a fixed 1.2V reference voltage. The current through this resistor is proportional to the bias current through the laser. In the MAX3738 the current in R_{MODSET} is approximately1/80th of the current in the laser. This means that an error in the bias resistor setting has 80 times greater effect on the bias setting.

The ratio of I_{Bias} to I_{MODSET} is variable within a range, as is the reference voltage across R_{MODSET}. The *Rejustor* is a precision adjustable resistor that can be adjusted in-circuit. Being able to adjust this resistor after assembling the laser module increases precision while reducing the variation in optical power from unit-to-unit.

3.2 Typical Application

The example in Figure 2 demonstrates *Rejustor* control for all the adjustments available with the MAX3738. The *Rejustor* connected to APCSET sets the desired optical power or bias current for the laser. The modulation amplitude is controlled with the *Rejustor* on MODSET.

A 15KΩ *Rejustor* on APCSET configures the average optical power in conjunction with the laser's back-facet detector. The modulation range combined with average optical power sets the extinction ratio. Modulation range is adjusted with a 15KΩ *Rejustor* on MODSET. Therefore, the extinction ratio can be trimmed using a Dual *Rejustor* MBD-153-A[2].

The *Rejustors* on PC_MON and BC_MON are adjusted to cause a logic threshold change when the current exceeds the maximum design specification. The MBD-103-A Dual 10KΩ *Rejustor* was chosen to set the maximum photodetector current (PC_MON) at 300µA and maximum bias current (BC_MON) in the range of 30mA. These values are dependant on the relationships provided in the laser datasheet.

[1] MAX3738 is a product of Maxim Integrated Products, Inc.
[2] Rejustor value is dependant upon the characteristics of the laser. Consult product datasheets for more information.

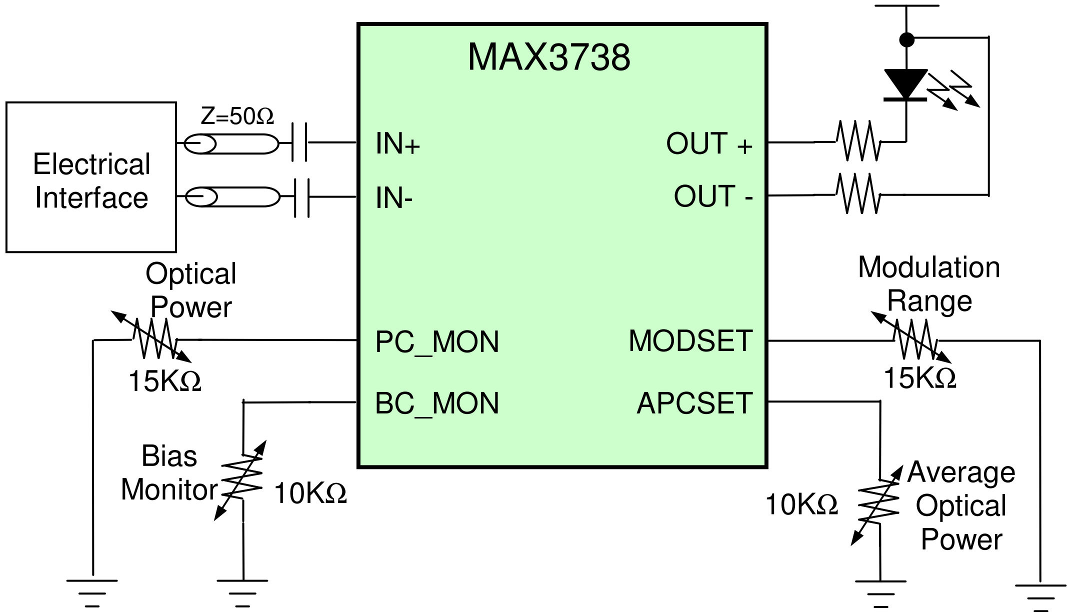

Figure 2: *Rejustor* Biased Laser Driver (details omitted for clarity)

The *Rejustor* based design provides a wide range of adjustment for laser bias current. Typically, however, a given laser operates within a much narrower range. The 30% trim range of the *Rejustor* does not limit its use in this application. The re-adjustable bias current resistor can be re-calibrated as the laser ages. Custom trimming tools could be deployed in the field to extend the life of older transmitters. Alternatively *Rejustors* become set-and-forget by removing or burying the trim pins at final assembly.

In a production environment each laser and driver can be quickly calibrated and re-calibrated as required.

4 Optical Receivers

Optical receivers convert light into electrical signals. There are usually two elements in a receiver module; a photodetector and an amplifier. A photon striking the surface of a semiconductor detector generates an electron-hole pair resulting in measurable current flow through the device.

As was the case with the transmitter, a semiconductor detector can be biased to optimize sensitivity and improve frequency response (bandwidth).

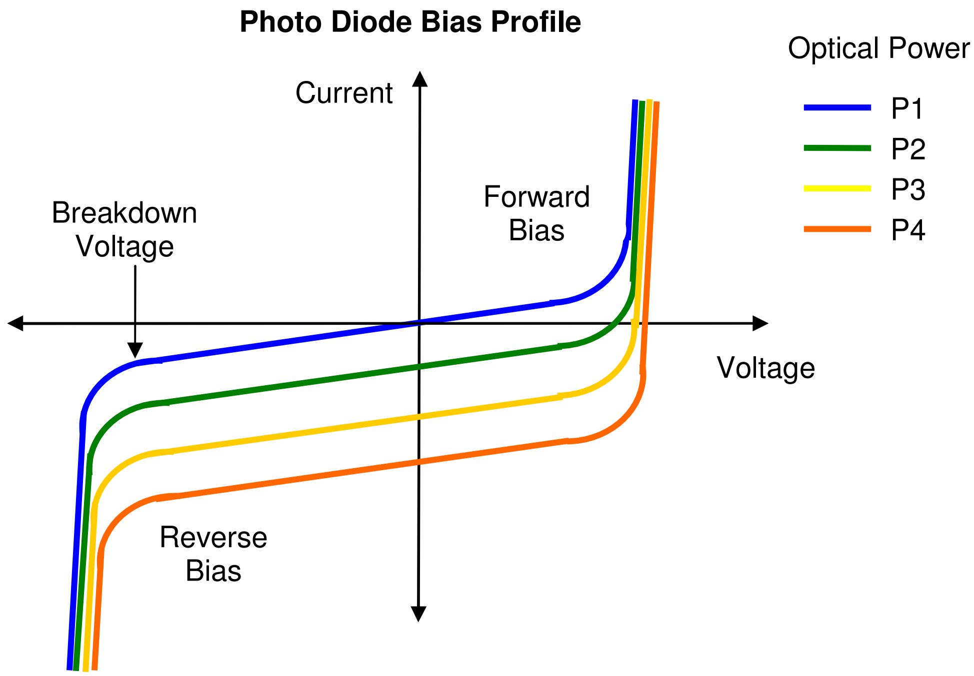

Figure 3: Photo-diode Response Profile

The photodetector needs to be biased between the forward conduction voltage (~0.7V) and the reverse breakdown voltage (tens of volts to hundreds of volts). Notice that the V vs. I response curve is linear in this region.

4.1 Conventional Photoconductive Mode

Figure 4, below, shows a *Rejustor* that can be trimmed to provide a fixed voltage at Vo for a range of photocurrent sensitivity. For example assume the photo-diode conducts minimum 56µA current when exposed to 1.0mW/cm². The product spec for the *Rejustor* and diode is 4.0V at Vo when exposed to 1.0mW/cm². A pair of 10KΩ *Rejustors* would be trimmed to achieve this requirement.

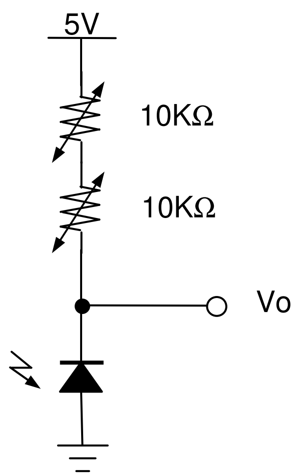

Figure 4: Basic Photoconductive Photodetector with *Rejustor* Control

4.2 Transimpedance Amplifier Compensation

Photo-diode current response is more linear than the voltage response. A Transimpedance amplifier (TIA) is conventionally used with a photo-diode to convert current to voltage. The *Rejustor* is an excellent choice for Transimpedance amplifier applications due to its inherently low capacitance.

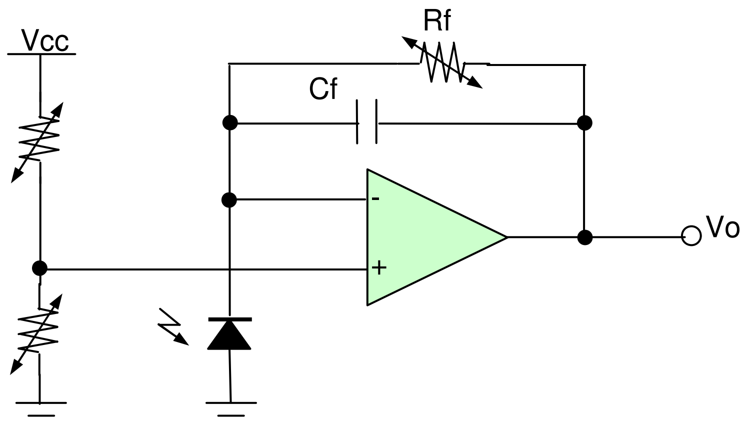

Figure 5: *Rejustor* Controlled TIA

The circuit shown in Figure 5 uses a photo-diode in photovoltaic mode to detect an optical signal. Transimpedance gain is controlled with *Rejustor* Rf. The *Rejustor* gain can be trimmed on a unit-by-unit basis to produce a high-precision receiver optical sub assembly (ROSA). The *Rejustor* divider combination on the non-inverting input of the TIA is used to create a zero-bias offset[3].

Refer also to the Microbridge Technologies *Rejustor* Based Amplifier Compensation white-paper (MB-APP-09-V01) for information about adjusting amplifier gain with *Rejustors*.

5 Summary

The compensation schemes presented here demonstrate the value *Rejustors* bring to optical subassemblies. Already proven in the area of passive compensation, these micro-resistors provide a flexible, convenient solution for small-signal compensation and amplification. The set and forget technology allows rapid adjustment and requires no bias current to maintain its value. These devices demonstrate high-stability in storage or operational life.

Rejustors provide a convenient solution to the problems associated with Laser-diode biasing. *Rejustors* can be trimmed to precisely adjust and maintain bias current and modulation amplitude. The versatile *Rejustor* was also used to set alarm levels for monitoring performance.

Photodetectors operate in either photoconductive mode or photovoltaic mode. *Rejustors* can be used to bias the receiver in the linear range regardless of photo-diode characteristics. Low capacitance and high-bandwidth allow *Rejustor* compensation for high-frequency optical detection using Transimpedance amplifiers.

We have focused on just a few of the many applications for small, precision adjustment using the *Rejustor*. Adjust your design!

[3] Many vendors set the dark voltage above 0V in order to improve the detection range for small signals with a ground-referenced amplifier.