

## The zero-switched laser diode driver

**Abstract.** This paper describes the most common causes of damage to medium power laser diodes. It proposed the idea of a new control system solves the problem. That concept involves switching the laser diode at a minimum voltage and current values. This paper describes a sample application of the new concept of the laser diode driver. Finally, the paper shows the possible directions of further development of the proposed controller.

**Streszczenie.** W publikacji omówiono typowe uszkodzenia diod laserowych średniej mocy. Przedstawiono w niej nową koncepcję układu sterującego, zabezpieczającego przed uszkodzeniami ESD. Idea koncepcji polega na włączaniu i wyłączaniu diody laserowej przy zerowych (minimalnych) wartościach napięcia i natężenia prądu zasilającego. Zaproponowano również przykładową implementację proponowanej koncepcji. W końcowej części przedstawiono kierunki dalszego rozwoju i możliwości innych zastosowań opisanego sposobu sterowania. (**Przełączalny w zerre sterownik diody laserowej**).

**Keywords:** CW laser diode driver, electrostatic discharge laser diode, controlled current source, digital current control.

**Słowa kluczowe:** stałoprądowy sterownik diod laserowych, uszkodzenia ESD diod, sterowane źródło prądowe, cyfrowa regulacja prądu.

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### Introduction

Laser diodes damage as result of optical or electrical overstress [1]. They are the result of an over-voltage or over-current operating conditions. Particularly sensitive to ESD are a low-power laser diodes. Starting from zero volts, the current vs. voltage profile is similar to LEDs [2,3]. Unlike the LED, laser diode current rapidly rises above the threshold voltage (1.3V in Fig.1). This is due to fundamental differences in the control of laser diodes as compared to the LEDs [4,5]. Further increase of the current above the maximum value results in damage to the laser diode. Therefore, it is important to monitor the maximum current, even in a short time. Equally dangerous for the laser diode is negative voltages.

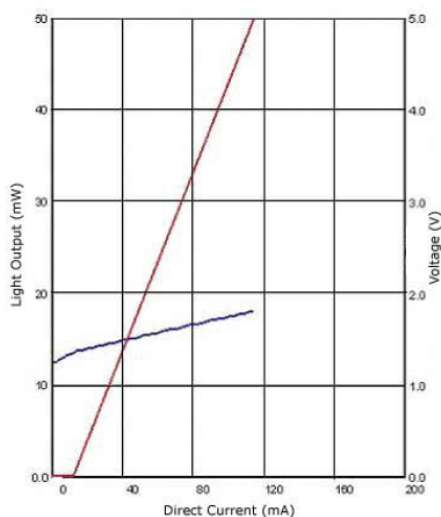


Fig.1. A typical characteristics of the low-power laser diode [6]

Electrostatic discharge (ESD) is a very common damage laser diodes. To understand the essence ESD damage can help Human Body Model (Fig.2) [7,8]. A 150 pF capacitor can charge to an above several thousand volts. During discharge the capacitor through the laser diode can pass a current of several amps. Of course the time such a large current flow is a few nanoseconds. This corresponds to a frequency of about 1 GHz. At such high frequencies, it is difficult to use conventional ESD protection. Standard safety features such as parallel resistor or capacitor, Schottky diode, varistor or relay and MOSFET switch do not work properly.

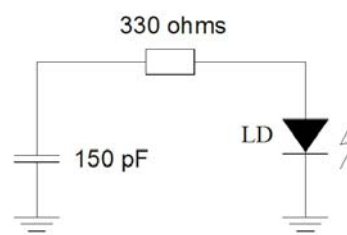


Fig.2. A Human Body Model

Shorting pin diode during installation does not always give 100 percent protection. For example, five centimeter copper braid (Fig.3) creates 50 percent risk of damage to the laser diode [1]. At a frequency 1 GHz round trip inductance is too large to protect the laser diode. It is true that there is some protection for selected values ESD voltages [1]. However, they do not cover the entire range of values. Thus, their usefulness is limited.

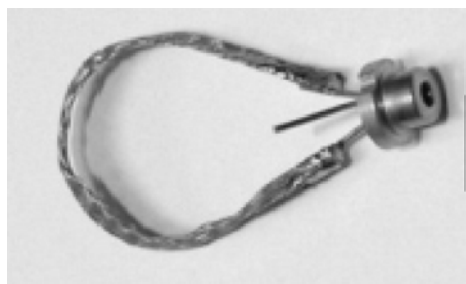


Fig.3. Shorting the terminals of the laser diode [1]

In addition to the ESD serious problem in the application of laser diodes are damaged during switching. When power is being turned on or off there are transition processes in circuit. This is an additional source of overvoltages. A good driver should smoothly turn on and off the power. Integrated solution drivers do not have built-in mechanisms in zero switching. An analog soft-start (Fig.4) does not protect against overvoltages. In the above figure the first curve is a switching signal. Its high level indicates the switch-on status of the driver [9]. When enabled, with some delay, we can see a soft-start of laser diode (second curve). It cannot be seen the effect of soft-stop when the laser diode is off.

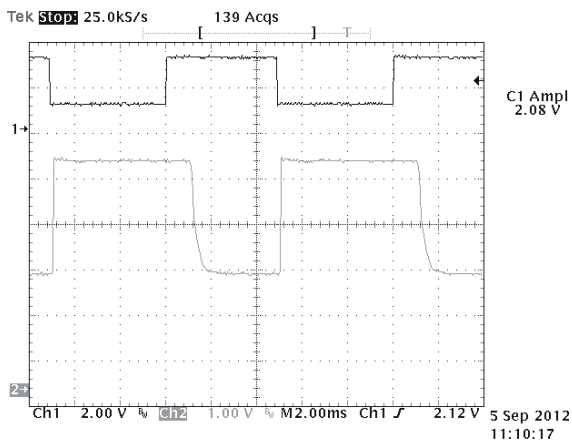


Fig.4. A transient characteristics of the integrated driver

In view of the above considerations was created the idea of the laser diode switching at zero voltage and current. The zero switching means turning on and off when the input bias current and the voltage drop across the diode is very small. When they are small enough not to damage the component.

### The idea of switching at zero

In simple terms, the concept is the simultaneous control of two parameters: the bias current and voltage across the diode. The bias current can be produced by the controlled current source  $I_{var}$  (Fig.5). At the same time laser diode the adjustable resistance  $R_{var}$  should short LD. The flow of a small current through the resistance of small value causes for the very small voltage drop. Thus, it is approaching zero switching condition.

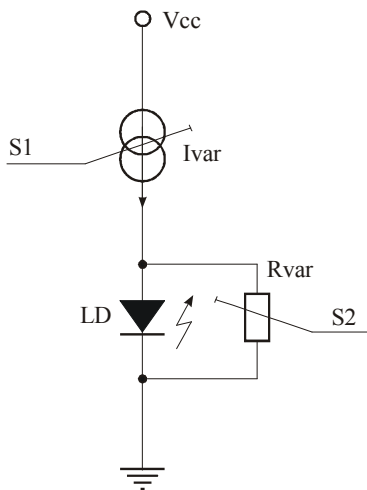


Fig.5. The functional diagram of the zero-switched driver

Shown in Figure 5 of the current source  $I_{var}$  should be regulated in a wide range of values. It must generate a current of either 1A and less than 1mA. The practical realization of this may require a multi-level control. The minimum value of the resistance  $R_v$  should not exceed tens of milliohms. The higher resolution of  $I_{var}$  and  $R_{var}$  we get the more precise will control the laser diode current. Two-parameter change of the laser diode operating point ensures a smooth on and off.

Turning on the system starts with small values current and voltage. Then, it is gradually increased until an operating point. During the shutdown is controlled variably

reduce the voltage and current. Control signals  $S1$  and  $S2$  must be active shortly before and after work laser diode.

The present control mechanism can be used not only in the switching process. Controlled, high resolution laser diode current can be applied in the steady state. It can also be used to shape the laser diode current supply for AC applications. The proposed approach is not limited to applications in laser diode drivers. This control method can also be used in controllers of light emitting diodes. The rest of the article proposed circuit driver that is based on the above control method.

### The sample application driver

The following figure shows a simplified diagram of a sample application driver. This is a very simplistic solution for checking the validity of the idea of control method.

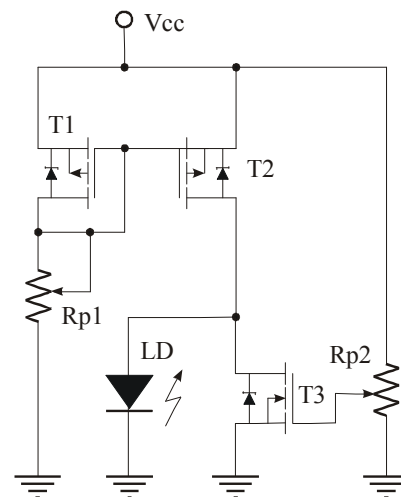


Fig.6. The sample application of the zero-switching idea

To carry out a regulated current source used in the application "current mirror" circuit. It consists of MOSFET transistors  $T1$  and  $T2$  and symbolic  $R_{p1}$  potentiometer. Assuming that the cathode of the laser diode LD is coupled to ground are used p-channel transistors. In this current source, a small current of the transistor  $T1$  controls the more current transistor  $T2$ . In the tested circuit, this ratio is approximately 1:1000. By adjusting potentiometer  $R_{p1}$  we change the current transistor  $T1$ . Thus controls the laser diode current.

In fact, the potentiometer  $R_{p1}$  is a more complex circuit. Single part will not provide the expected range of current control. On the other hand, the stability of the power transistor  $T1$  depends on the quality control of the laser diode. For these reasons, analog potentiometer can be replaced by a cascade connection such as digital potentiometers. The lower terminal of symbolic  $R_{p1}$  potentiometer should not be connected to ground, but the output of the reference voltage source. Of course, digital potentiometers require a digital signal control them. This is not a limitation since the final driver required other digital signals. Such signals can be generated for example by a small FPGA chip.

As for the transistor  $T3$ , it should be chosen very carefully. Its  $R_{DS(on)}$  (Drain-Source On-State) resistance directly determines the quality control. The value of this resistance is lower the lower is possible to obtain the value of resistance  $R_{var}$  in Figure 5. Its value is determined directly possible to achieve the minimum voltage drop across the laser diode. Currently, there are transistors with resistance  $R_{DS(on)}$  of less than 1mΩ. Unfortunately, so far

these are the power transistors. So far, they are not produced in this class small signal transistors. The test driver model, applied transistor T3 drain current up to 75A. In a real system would replace the potentiometerRp2 more complex structure of the digital potentiometers.

Due to the energy efficiency of the driver should be supplied at the lowest voltage  $V_{cc}$ . This requires the use of a current source transistors as low a drain-source on-state resistance. In the system under study, supplied 5V and contained typical MOSFETs, were obtained minimum voltage drop across the laser diode of about 10mV. Thus, it was confirmed that it is possible to turn the laser diode at the minimum (zero) voltage. This proves the point further development of the proposed methods of controlling the low-power laser diode.

## Conclusion

Presented the concept of zero switching laser diode helps protect against damage ESD element. It also allows the free development transient characteristics of the supply current at low frequencies. The method is based on two parametric control current source power laser diode. This paper presents a simple scheme of the application, verifies the proposed control method. Received, preliminary results confirm the desirability of further research in this area. Especially that the solution can be transferred to other areas of application, such as LEDs control.

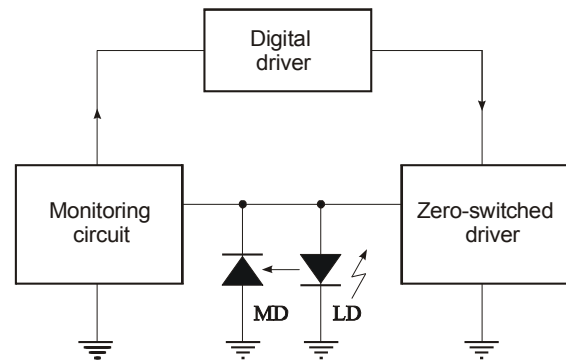
Presented in the publication of a simple application scheme is not a complete laser diode driver. Each laser diode to work properly requires flux stabilization in feedback. Therefore, the proposed solution needs to be built into the system shown in Figure 7.

This system includes, as discussed above, the zero-switched laser diode driver. The laser diode is optically coupled monitoring photodiode *MD*. The photodiode measures the actual value of the radiation emitted by the laser diode in. Measured flux causes a proportional current flow in the photoelectric monitoring system (*Monitoring circuit*). The intensity of the photocurrent is converted to a proportional of the digital signal. The resulting digital signal is fed to the input of digital control unit (*Digital driver*).

The control unit on the basis of the assumed bias current laser diode and the measured photocurrent produces digital feedback error signal. This signal controls the digital potentiometer settings discussed laser diode driver, forcing increasing or decreasing the diode bias current. Transition state continues until the error signal is in the acceptable range of values. In fact, the digital driver must handle complex concurrency control algorithm for multiple signals. It is difficult to achieve on a single microprocessor chip. The microprocessor-based implementation or lead to a complex microprocessor system or a complex program to use. Therefore, an alternative solution in this case seems to be the use of the FPGA or CPLD chips.

The publication omitted temperature stabilization problem of the driver. For proper operation of the laser diode it is a very important issue. Temperature operating pint changes cause changes in the spectral emission characteristics of the laser diode. Spectrally they deregulate the entire system. A properly designed driver should solve the problem of temperature stabilization. In the literature we can find some way to solve this problem. Some of them [10] use the systems based on Peltier modules. On the laser

diode heat sink is mounted digital thermometer, which measures the current temperature. On the basis of the expected and the measured temperature, the control unit changes in the digital supply current Peltier module.



Rys.7. The complete block diagram of the zero-switched driver

The paper describes only a selected part of a wider study. Several issues signalled in the diagram of Figure 7 require the development and testing. Digital control of the current operating point of the laser diode seems to be the right direction for development. Further studies will be presented in the near future.

## Acknowledgments

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