International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 3, Issue 4 (November 2013) PP: 56-60

Method to control the output power of Laser in the variation of Ambient Temperature

Ghanshyam Kumar Singh
Department of Electronics and Communication Engineering, School of Engineering and Technology, Sharda University, Greater Noida 201 310, India

Abstract: *This paper presents a method to control the output power of Laser in the variation of ambient temperature. The circuit was designed using a feedback loop to maintain a constant optical power in the presence of temperature variation. It has been shown that the small variation in the photo-detector current, in response to a small variation of the laser output power, the PI controller adjusts the bias voltage so that the current through the laser remains constant. As a result, the output optical power is kept constant. The OptiSpice software has been used which incorporates equations governing optical components directly into an electrical stimulation.*
Keywords: *Laser, Photo-detector, PI Controller & OptiSpice.*

I. INTRODUCTION

Operating temperature affects the performance and reliability of most electronic and optoelectronic devices. Fundamental properties of semiconductors such as band structure, probability distribution of charge carriers, and transport properties are strongly dependent on temperature. For example, the dielectric constant and other optical properties are based on inter-band electronic transitions for which the magnitude (oscillator strength), line-width, and peak energy all vary upon temperature changes. Phonons and electrical carriers, which carry heat, have occupation probabilities and scattering rates that are all temperature-dependent [1-6].

In this work, it has been demonstrated that the output power of Laser can be maintained in the variations of the ambient temperature using the proposed circuit design. The OptiSpice software has been used which incorporates equations governing optical components directly into an electrical simulation framework, thus forming a single-engine optoelectronic simulation tool. Previously, the ability for a single software package to tightly model optical-electrical integration, thermal coupling, and various optical effects (such as interference, reflection, and multiple carrier frequencies) was non-existant.

II. POWER CONTROL DESIGN

In this design, we have used a proportional-integral-derivative controller (PID controller) which has a generic control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. In PID tuning a control loop is the adjustment of its control parameters (proportional band/gain, integral gain/reset, derivative gain/rate) to the optimum values for the desired control response. Stability (bounded oscillation) is a basic requirement, but beyond that, different systems have different behavior, different applications have different requirements, and requirements may conflict with one another.

PID tuning is a difficult problem, even though there are only three parameters and in principle is simple to describe, because it must satisfy complex criteria within the limitations of PID control. There are accordingly various methods for loop tuning, and more sophisticated techniques are the subject of patents [7-8].

Designing and tuning a PID controller appears to be conceptually intuitive, but can be hard in practice, if multiple (and often conflicting) objectives such as short transient and high stability are to be achieved. Usually, initial designs need to be adjusted repeatedly through computer simulations until the closed-loop system performs or compromises as desired.

The figure below illustrates a circuit design using a feedback loop to maintain a constant optical power in the presence of temperature variation.

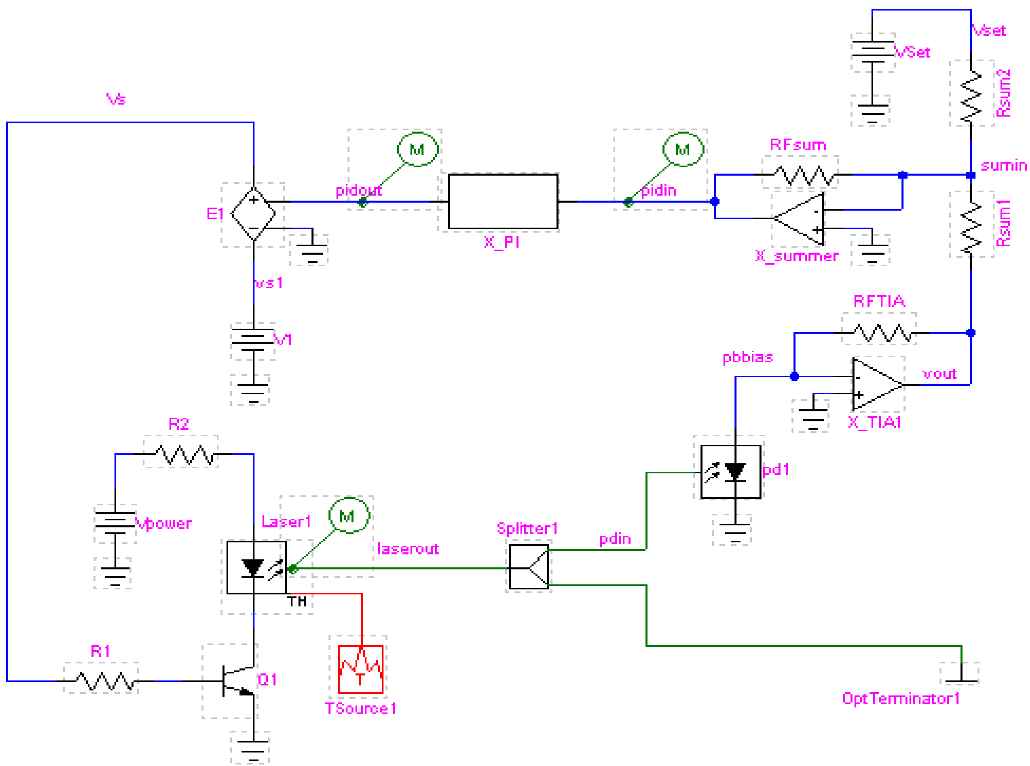

Fig. 1. Power control design

A small percentage of the optical power is split off from the output of the laser and is fed to a photodetector. The output from this detector is used as the input to a closed loop PI controller (see Figure 2). For any small variation in the photodetector current, in response to a small variation of the laser output power (ex. due to temperature change), the PI controller adjusts the bias voltage so that the current through the laser remains constant. As a result, the output optical power is kept constant.

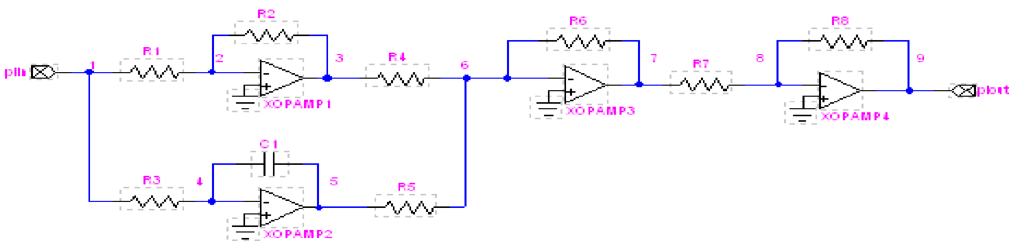

Fig. 2. PI controller subcircuit

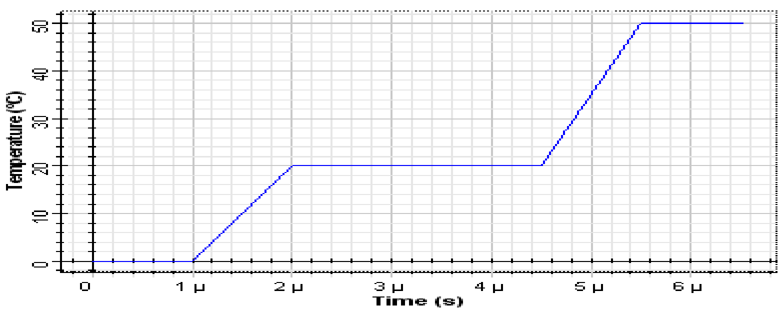

Fig. 3. Laser temperature

In this design ambient temperature of the laser is varied with time as shown in Figure 3. This temperature variance is fed to the laser through an external thermal source.

III. RESULTS & DISCUSSION

The power control design was simulated using a SPICE engine that incorporates both electrical and optical models – OptiSPICE. It cannot be simulated using traditional software packages that rely on co-simulation or equivalent circuit models, as they do not provide sufficient coupling between electrical and optical devices. The response of the laser output power is shown in Fig. 4. Responses for two cases are shown – closed and open loop cases. As expected, closing the PI feedback loop causes the laser bias to be adjusted to compensate for the temperature changes.

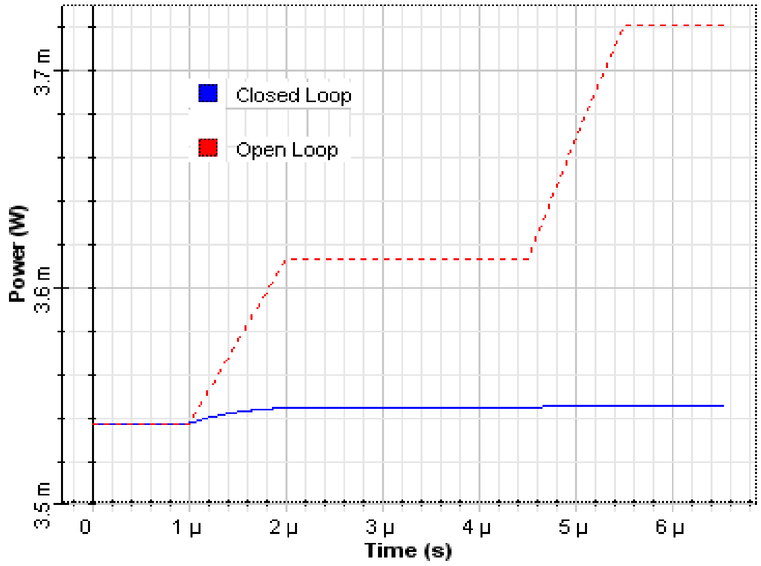

Fig. 4. Laser output power

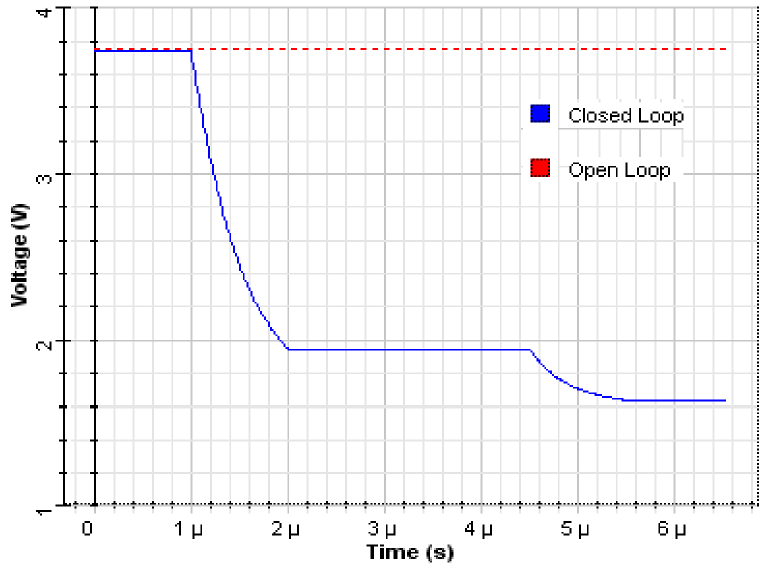

Fig. 5. Bias voltage

Fig. 5 shows the bias voltage for the closed and open loop cases. It can be observed from the plot that bias voltage is getting reduced to compensate the increase of temperature in the closed loop case.

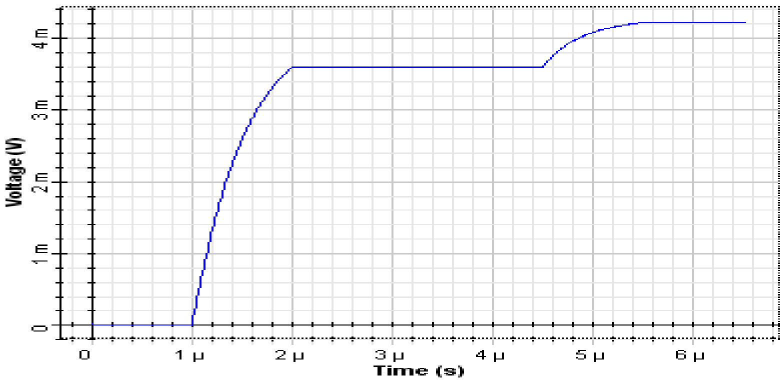

Fig. 6. Input voltage of the PI controller

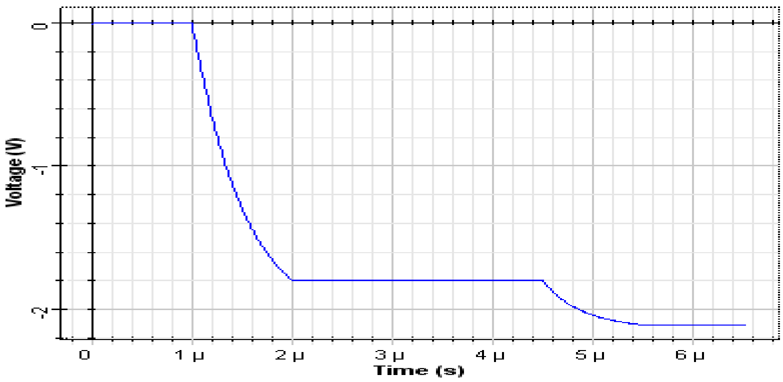

Fig. 6. Output voltage of the PI controller

Figs. 6 and 7 show input and output voltage of the PI controller. As it can be seen a very small increase in the input (in the order of mV) causes a significant negative voltage in the output. However, the stability of PI controller is a major concern. The PID controllers are applicable to many control problems, and often perform satisfactorily without any improvements or even tuning, they can perform poorly in some applications, and do not in general provide optimal control. The fundamental difficulty with PID control is that it is a feedback system, with constant parameters, and no direct knowledge of the process, and thus overall performance is reactive and a compromise – while PID control is the best controller with no model of the process, better performance can be obtained by incorporating a model of the process.

The most significant improvement is to incorporate feed-forward control with knowledge about the system, and using the PID only to control error. Alternatively, PIDs can be modified in more minor ways, such as by changing the parameters (either gain scheduling in different use cases or adaptively modifying them based on performance), improving measurement (higher sampling rate, precision, and accuracy, and low-pass filtering if necessary), or cascading multiple PID controllers.

PID controllers, when used alone, can give poor performance when the PID loop gains must be reduced so that the control system does not overshoot, oscillate or hunt about the control set-point value. They also have difficulties in the presence of non-linearities, may trade-off regulation versus response time, do not react to changing process behavior and have lag in responding to large disturbances.

IV. CONCLUSION

A method to control the output power of Laser in the variations of ambient temperature is presented. The ideal schematic was designed using a feedback loop to maintain a constant optical power. The PID controller design also presented and discussed. It has been shown that the small variation in the photo-detector current, in response to a small variation of the laser output power, the PI controller adjusts the bias voltage so that the current through the laser remains constant. As a result, the output optical power is kept constant. PID controllers are often enhanced through methods such as PID gain scheduling, fuzzy logic or computational verb logic. Further practical application issues can arise from instrumentation connected to the controller. A high enough sampling rate, measurement precision, and measurement accuracy are required to achieve adequate control performance. Another new method for improvement of PID controller is to increase the degree of freedom by using fractional order. The order of the integrator and differentiator add increased flexibility to the controller. The OptiSpice software has been used which incorporates equations governing optical components directly into an electrical simulation.

REFERENCES

[1]. Betser, Y.; Lasri, J.; Sidorov, V.; Cohen, S.; Ritter, D.; Orentstein, M.; Eisentstein, G.; Seeds, A.J.; Madjar, A., "An integrated heterojunction bipolar transistor cascode opto-electronic mixer," *Microwave Theory and Techniques, IEEE Transactions on* , vol.47, no.7, pp.1358,1364, Jul 1999

[2]. Cappelluti, F.; Traversa, F.L.; Bonani, F.; Guerrieri, S.D.; Ghione, G., "Large-Signal Stability of Symmetric Multibranch Power Amplifiers Exploiting Floquet Analysis," *Microwave Theory and Techniques, IEEE Transactions on* , vol.61, no.4, pp.1580,1587, April 2013

[3]. Simpson, T.B.; Jia-Ming Liu; AlMulla, M.; Usechak, N.G.; Kovanis, V., "Linewidth Sharpening via Polarization-Rotated Feedback in Optically Injected Semiconductor Laser Oscillators," *Selected Topics in Quantum Electronics, IEEE Journal of* , vol.19, no.4, pp.1500807,1500807, July-Aug. 2013.

[4]. Eliyahu, D.; Maleki, L., "Modulation response (S21) of the coupled opto-electronic oscillator," *Frequency Control Symposium and Exposition, 2005. Proceedings of the 2005 IEEE International* , vol., no., pp.850,856, 29-31 Aug. 2005 Bin Hashim, A.; Bamiedakis, N.; Penty, R.; White, I., "Multimode Polymer Waveguide Components for Complex On-Board Optical Topologies," *Lightwave Technology, Journal of* , vol.PP, no.99, pp.1,1, 2013

[5]. Kroh, M.; O'Keefe, M.; Voigt, K.; Fedderwitz, S.; Battista Preve, G.; Lischke, S.; Brast, T.; Petousi, D.; Stamatiadis, C.; Kehayas, E.; Nogueira, R.; Korn, D.; Roccato, D.; Schindler, P.C.; Lazarou, I.; Koos, C.; Freude, W.; Leuthold, J.; Avramopoulos, H.; Steffan, A.G.; Stampoulidis, L.; Zimmermann, L., "Photonic - Electronic platform for next generation optical transport network," *Transparent Optical Networks (ICTON), 2013 15th International Conference on* , vol., no., pp.1,5, 23-27 June 2013

[6]. "Circuit for controlling the output power of an uncooled laser or light emitting diode", B Glance, KY Liou - US Patent 5,907,569, 1999

[7]. "Device and method to control the output power of laser diodes", JF Queniat, A Jaillard - US Patent 5,383,208, 1995