DRIVER FOR LOW POWER THERMOELECTRIC SENSOR TEMPERATURE STABILISING COOLER

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Abstract - *A new thermoelectric cooling system (TEC) was developed based on the Peltier. The driver drives the TEC (a Peltier element) to keep the temperature of the device under test (a laser diode) at a constant value. A NTC thermistor (placed in close contact to a device under test) measures the temperature. The Peltier driver consists of an input resistance bridge, an error amplifier, a PI regulator and a driver. The long time stability and the temperature stability of the Peltier driver itself are excellent. The Peltier driver can be implemented on-chip, too. Only a few external components should be necessary to use. Also a digital setting of the temperature can be implemented easily.*

Keywords - *Thermoelectric cooler, TEC, Peltier element, Peltier driver, PI regulators,* ***,*** *Steinhart-Hart equation*

1. INTRODUCTION

Physical parameters of any existing system depend on the temperature. It is also true for an electrical system. Resistance of resistive materials, conductance of wires and conductance of semiconductors are influenced by the temperature. Therefore, for stable operation of an electrical or optoelectronic system the stable temperature is required.

Typical example can be a source of reference voltage. Although special design techniques are used to minimize the temperature dependency, for very stable operation the constant temperature is needed. Another example can be represented by a source of light with constant wavelength – laser. The wavelength λ is strongly dependent on the temperature. Therefore, for very stable operation of the laser diode the constant temperature is needed, too. To keep the devices on the temperature lower then ambient temperature, or ambient temperature plus warming proportional to power dissipation, the thermostat is used

2. DETAILED DESCRIPTION

A new thermoelectric cooling system (TEC) was developed based on the Peltier. TEC regulator and driver block diagram of the Peltier driver is shown in Fig. 1.

The driver drives the TEC (a Peltier element) to keep the temperature of the device under test (a laser diode) at a constant value. A NTC thermistor (placed in close contact to a device under test) measures the temperature. The Peltier driver consists of an input resistance bridge, an error amplifier, a PI regulator and a driver. The driver converts this output voltage into current, which affects the Peltier element temperature directly. The thermal connection Peltier element - NTC terminates the regulation loop and forms its feedback.

Resistance of the thermistor R_{NTC} can be derived from the Steinhart-Hart equation

$$1/T = A + B \ln R_{NTC} + C(\ln R_{NTC})^3$$

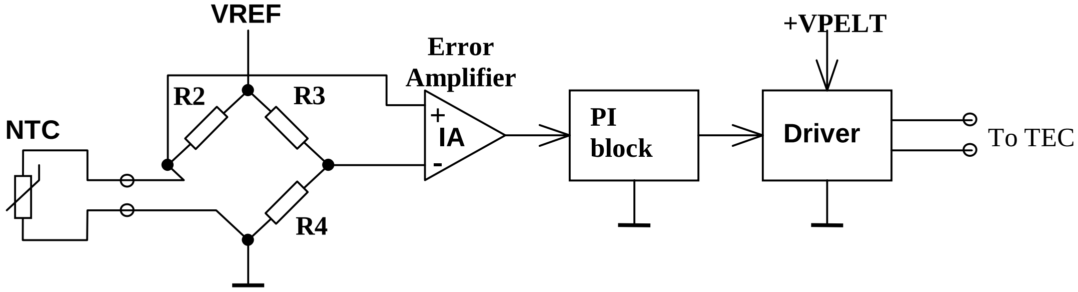

Fig. 1: *Block diagram of the Peltier driver*

where T is temperature (K), InR_{NTC} is the natural log of the thermistor resistance (base e), A, B, & C are equation constants derived from measurements. The exponential expression is the approximation of Resistance ~ Temperature characteristics for NTC thermistor elements. At present the Steinhart-hart equation has wide industry expectance as the most useful equation for precise thermistor R-T calculation. The Steinhart-hart equation stands for an empirical third degree polynomial equation expression. The following block of the Peltier driver is the PI regulator. It consists of a proportional element and integrating element. The last part of the Peltier drive is a precision current source, which supplies directly the TEC Peltier element. Thermoelectric coolers require smooth DC current for optimal operation [2]. Voltage or current limiting should be used in order to ensure that maximum current for the TEC is not exceeded.

3. PELTIER DRIVER PROTOTYPE

A prototype of the Peltier driver was built and measured. The load of the Peltier driver was a TEC inside the SDL-5400 laser diode [3]. The laser diode package comprised the laser diode itself, the TEC and the NTC 10 kΩ thermistor. Therefore, there was a close thermal contact between the TEC, the NTC thermistor and the laser diode. The laser diode was driven by 90 mA constant current; therefore the power dissipation of the laser diode increased the temperature of the laser diode package about 5 °C above ambient temperature.

The first parameter tested was the temperature and the long time stability of the Peltier driver itself. Therefore, the Peltier driver was located inside the temperature-regulated oven. The second parameter tested was the stability of the laser diode temperature, when the ambient temperature was changing. Therefore, the ambient temperature in the laboratory directly influenced the laser diode. The temperature was set to 19.14 °C.

The waveform of the temperature inside the laboratory and inside the regulated oven is shown in Fig. 3. The Peltier driver was located inside the regulated oven. The laser diode was placed on the table influenced only by the ambient temperature in the laboratory.

The measurements started when the temperature in the oven was stabilized at 32.5 °C for about 1 hour. After 8.9 hours, the temperature inside the oven was set to 40.5 °C. The temperature 40.5 °C was reached at 9.30 hour.

The stability of the laser diode temperature was tested. The graph of the laser diode temperature and its error is shown in Fig. 3. All errors are referred to the first measured point. The desired temperature set point was reached after 0.1 hours. At 7.7 hours was the laser diode heated (for a few minutes) by a human hand to a temperature, which is close to the human

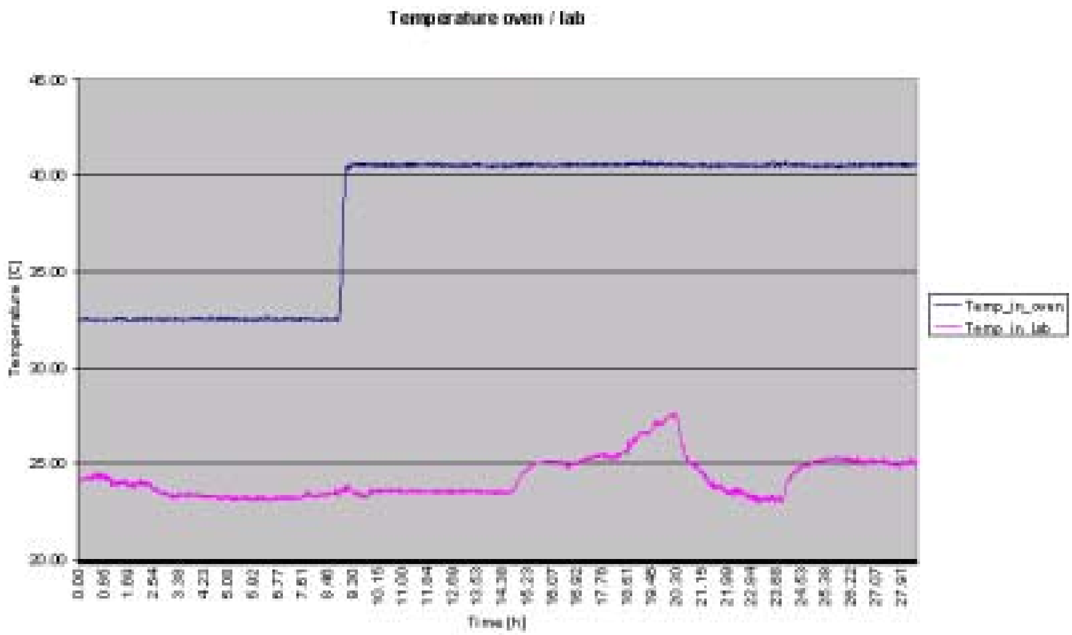

Fig. 2: *Ambient temperature in the laboratory and temperature in the oven*

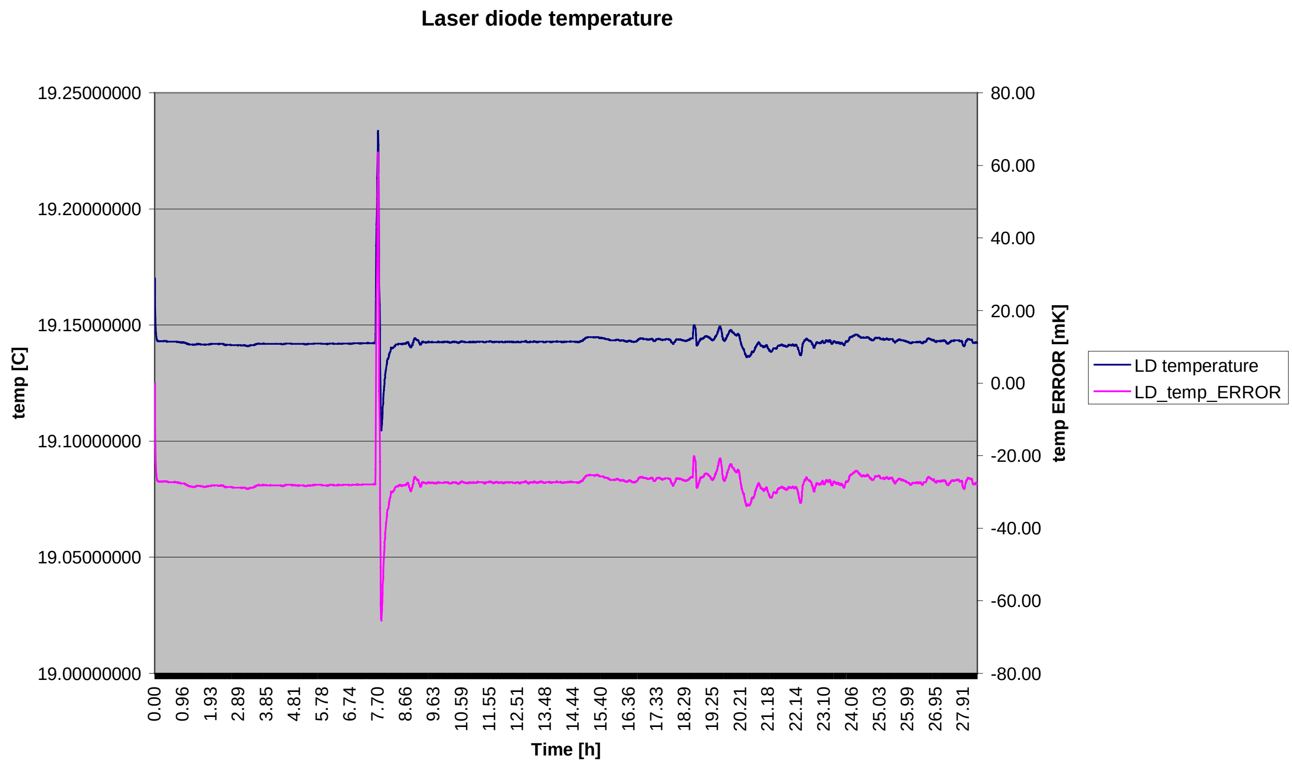

Fig. 3: *Plot of the laser diode temperature*

body temperature. After this "short heating procedure", the laser diode was placed on the table again. As can be seen from Fig. 3, the cooling regulator acts like a critically damped system. Note that the PI constants of the Peltier regulator have not been tuned for the type of used laser-Peltier diode. Therefore we can expect better behaviour after tuning the PI constants.

The long time stability and the temperature stability of the Peltier driver itself are excellent, as can be seen in Fig. 3. The set temperature does not depend on the Peltier driver ambient temperature. The laser diode temperature was kept inside the +/- 10 mK range, when the ambient temperature of the laser diode was changing 'naturally' (no step changes). Note that the PI constants were not tuned for the laser diode used. The Peltier driver can be implemented On-chip also. Only a few external components should be necessary to use. Also a digital setting of the temperature can be implemented easily.

4. CONCLUSION

This paper presents an application that can offer a design pattern for using Peltier element for long-term temperature high stabilizing of electronic devices. The kernel of the paper focuses on the driver for low power thermoelectric sensor temperature stabilising cooler as an universal project, stressing the easy stabilizing of sensing electronic devices for especially non-electric quantities measurements.

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