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Implementing of a precision fast thermoelectric cooler controller using a personal computer parallel port connection and ADN8830 controller

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A complete design of a compact precision and fast thermoelectric cooler (TEC) controller with a parallel port connection to a personal computer (PC), using a pulse width modulation technique by a dedicated smart driver, and digital control designed using very high-speed integrated circuit hardware description language is presented. The design allows replacement of the PC with an ‘‘on board’’ embedded microcontroller. This circuit is demonstrated as a TEC controller for a high-speed electro-optical modulator. © *2003 American Institute of Physics.* [DOI: 10.1063/1.1589159]

I. INTRODUCTION

Temperature control is needed for a wide range of applications. For some, a precision of ±1 °C is satisfactory, but critical applications require precision of 0.1 °C and sometimes even 0.01 °C. For example, the performance of optoelectronics devices (diodes lasers, photodiodes, electro-optic modulators, etc.) depend strongly on temperature; hence, these devices require high precision temperature control. Moreover, in several systems, it is not enough to regulate the temperature to a constant value, but instead, an optimization procedure is required. In systems like these, a feedback control mechanism (or user) varies the target temperature to maximize the output signal from the device under control.

Thermoelectric coolers (TECs)[1–3] are solid-state heat pumps that operate according to the Peltier effect[4]—a heating or cooling effect when an electric current passes through two conductors. A voltage applied to the free ends of two dissimilar materials creates a temperature difference. With this temperature difference, Peltier cooling will cause heat to move from one end to the other. A typical thermoelectric cooler will consist of an array of *p*- and *n*-type semiconductor elements that act as the two dissimilar conductors. The array of elements is soldered between two ceramic plates, electrically in series and thermally in parallel. As dc current passes through one or more pairs of elements from *n* to *p*, there is a decrease in temperature at the junction (‘‘cold’’) resulting in the absorption of heat from the environment. The heat is carried through the cooler by electron transport and released on the opposite (‘‘hot’’) side as the electrons move from a high- to low-energy state. The heat pumping capacity of a cooler is proportional to the current and the number of pairs of *n*- and *p*-type elements.

II. DESIGN CONSIDERATIONS

The controller presented here was developed to operate with a 1A/5V TEC,[5] at room temperature, and connect to a personal computer (PC) via the standard parallel port—to set the target temperature (and monitor some other signals). It is shown that by integrating a digital control, and regulating the TEC by pulse width modulation (PWM) with a dedicated smart driver with proper protection mechanisms, one can implement a compact, reliable, accurate, and safe system at relatively low costs. This controller has a temperature control range of 0–50 °C, a precision of 0.1 °C, and a time constant of few seconds, using a small printed circuit board (PCB) of 2.5 in.×4.0 in. in size.

The initial consideration in the design was to choose the regulation method (PWM or linear). To achieve a compact design without cooling elements, a high-frequency PWM technique was chosen with a small coil filter. A high-frequency PWM technique combines the advantages of high efficiency energy transfer (the switching element does not waste any energy) and a very low ripple at the output. As just mentioned, the TEC heat pump capacity is proportional to the current flow through the device, that means that by inverting the current direction, one converts the cooler to a heater and vice versa. To improve the controller performance, the TEC is driven with a bidirectional current, switched by full-bridge solid-state devices. The bridge driver consists of a couple of complementary metal–oxide–semiconductor field-effect transistor-FDW2520C,[6] which can hold 20 V/5 A and has a switching time of ~20 ns.

III. ELECTRONIC CIRCUIT

Figure 1 is a block diagram of the circuit. The circuit is composed of three blocks: a digital control, a smart analog proportional integral differential (PID) controller for the PWM bridge, and eight-channel 12 bits data acquisition unit. In order to eliminate mutual interference between the three blocks, each one has its own power and ground supply terminals. The TEC is connected to a J_1 connector while the temperature sensor is connected to a J_2. Figure 2 depicts the smart PWM analog PID controller unit and the power-switching bridge. Each one of U_6 and U_8 is a half bridge, while both compose the full-bridge driver for the TEC. The bridge output signal is filtered by L_1 (Coilcraft DO3316P-472)[7] and C_{26} (Cornell Dubilier ESRD220M08B)[8] to eliminate any ac voltage level on the

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