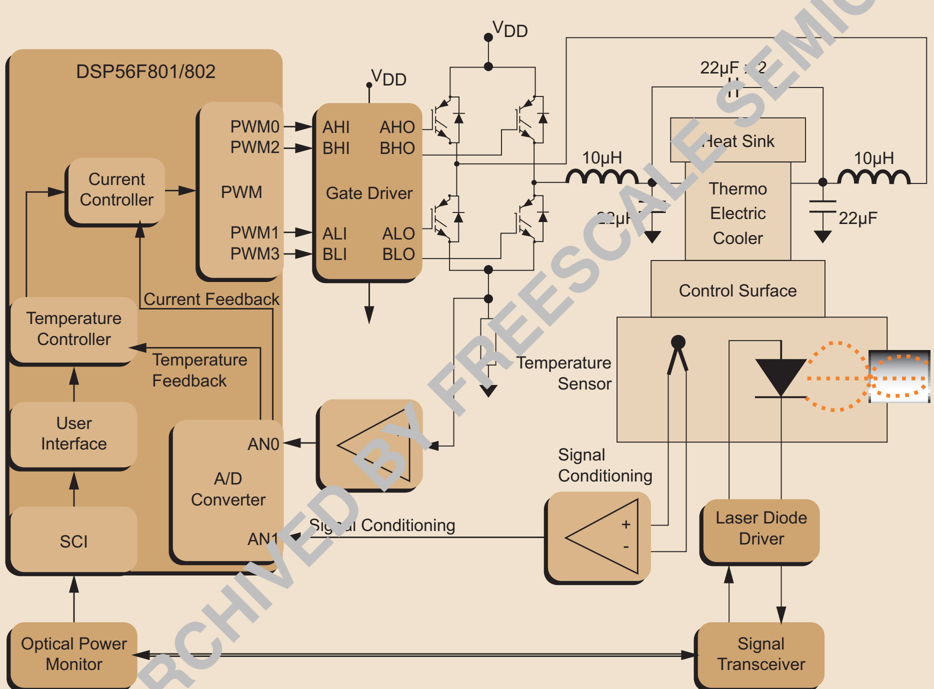
Thermoelectric Cooler Temperature Control

Overview

Thermoelectric coolers (TECs) employ the Peltier effect, acting as small, solid-state heat pumps. The TECs are ideally suited to a wide variety of applications where space limitations and reliability are paramount. The TECs operate on DC current and may be used for heating and cooling by simply reversing the direction of the DC current.

The DSP56F801/802 provides a low-cost and high-performance solution for TEC control. Earlier systems used many analog circuits to perform temperature control; the use of DSP allows the task to be handled by software.

TEC APPLICATION FOR OPTICAL MODULE CONTROL – CONTROLLING A LASER'S WAVELENGTH BY REGULATING THE TEMPERATURE OF THE LASER DIODE



Key Benefits

- > Provides high operation efficiency
- > Provides low current ripple
- > Offers long-term temperature stability
- > Provides a full-bridge controller for bidirectional current
- > Provides programmable switching frequency that reduces filter component size and noise
- > Offers a PID control loop that improves the transient response
- > Presents a single-device solution that combines MCU functionality and DSP processing power
- > Provides out-of-the-box software components that are designed to expedite time-to-market and reduce development costs

Freescale Ordering Information

Part Number	Product Highlights	Additional Information
DSP56F801	800 MHz, 40 MIPS, SCI, SPI, ADC, PWM, Quad Timer and > 8K Program Flash > 1K Program RAM > 2K Data Flash > 1K Data RAM	MCU-friendly instruction set, OnCE for debug, on-chip relaxation oscillator, 2K boot Flash and up to 11 GPIO available in a 48-pin LQFP
DSP56F802	800 MHz, 40 MIPS, SCI, SPI, ADC, PWM, Quad Timer and > 8K Program Flash > 1K Program RAM > 2K Data Flash > 1K Data RAM	MCU-friendly instruction set, OnCE for debug, on-chip relaxation oscillator, 2K boot Flash and up to a 4 GPIO available in a 32-pin LQFP
MC56F8300	60 MHz, 60 MIPS, up to 576KB Flash, 36KB RAM and Off-Chip Memory, SCI, SPI, ADC, PWM, Quadrature Decoder, Quad Timer, FlexCAN, GPIO, COP/Watchdog, PLL, MCU-style software stack support, JTAG/OnCE for debug, temperature sensor	www.freescale.com
MC56F8100 Family[Note]	40 MHz, 40 MIPS, up to 544KB Flash, 32KB RAM and Off-Chip Memory, SCI, SPI, ADC, PWM, Quadrature Decoder, Quad Timer, FlexCAN, GPIO, COP/Watchdog, PLL, MCU-style software stack support, JTAG/OnCE for debug	www.freescale.com
MC56F801x Family	Up to 32 MHz, 32 MIPS, and up to 16KB Flash, 4KB Unified Data/ Program RAM, EEPROM emulation capability, SCI with LIN, SPI, I^2C, ADC, PWM, GPIO, COP/Watchdog, MCU-style software stack support, JTAG/OnCE for debug	www.freescale.com

Note: MC56F8122 and MC56F8123 are not appropriate for this application.

Design Challenges

Thermoelectric coolers (TECs) are solid-state heat pumps that have no moving parts and do not require the use of harmful chemicals. The ability to use TECs to heat as well as cool benefits applications that require temperature stabilization of a device over a wide ambient temperature range, such as laser diode, portable temperature chambers, and airborne equipment. A bidirectional DC current is required for those applications requiring both heating and cooling. The TEC requires a smooth DC current for optimum operation. A ripple factor results in degradation in delta T. A number of methods can be used to regulate the magnitude and direction of the TEC current. Liner regulation can be used but it is very inefficient and requires a bipolar power supply. The pulse width modulation (PWM) technique can be used to improve the efficiency and reduce overall system size, as long as its switching freqencies are above 5 kHz with suitable LC filters. To suppress temperature fluctuation because of ambient temperature variation and uncertainties of the load condition, the controller must be capable of either sourcing or removing heat to maintain control without temperature overshoot or undershoot. These requirements can be met by implementing closed-loop control for both heating and cooling. To minimize temperature variation, the PID control or other advanced control algorithms, such as adaptive PID control, must be used to enhance the system stability.

Freescale Semiconductor Solution

The figure on page 1 shows a typical TEC application for optical module control that is commonly used to control laser wavelength (or color) by regulating the temperature of the laser diode. The circuit uses the DSP56F801 or DSP56F802 as the controller; a power output stage; a differential LC filter; and a TEC module to form a closed-loop temperature regulator. The dual-loop control scheme is utilized. The inner loop is a current feedback loop that can increase system robustness and improve system response. A PWM frequency of over 50 Khz with 50 ns resolution is generated by an on-chip PWM module that includes many features, such as deadtime insertion, complimentary outputs, and polarity control. The frequency is chosen as a compromise to limit switching losses in the power stage while minimizing the size of the LC filter. The center-aligned PWM mode is chosen to eliminate even-order current harmonics. The deadtime between commutation of power stage switches is programmable and automatically inserted while commutation occurs. The appropriate ratio of deadtime and PWM period is key to ensure high control accuracy and that circuits in power stages are not shortened.

The current flow to TEC is sensed by a resistor shunt and fed to the ADC input. The on-chip ADC is a 12-bit ADC with a maximum sampling rate of up to 1.7 million samples per second. The ADC conversion can be synchronized to the PWM module where ADC is triggered at a specific time delay after the PWM reload signal is generated. With this synchronization feature, PWM switching interference can be avoided and current flow direction can be detected. Each ADC channel has unique registers associated with it that can generate an interrupt when the input crosses zero or certain thresholds. These are extremely useful for detecting fault conditions, such as overcurrent or overtemperature.

The control components, such as temperature setting, button, and display, are connected to the on-chip communication peripherals, SCI and SPI (DSP56F801 only). In this application, the external crystal oscillator can be eliminated by using the on-chip relaxation oscillator that helps to reduce system cost.

Development Tools

Tool Type	Product Name	Vendor	Description
Software	Processor Expert	Freescale Semiconductor	Software infrastructure that allows development of efficient, high-level software applications that are fully portable and reusable across all 56800/E family of processors.
Software	CWDSP56800	Freescale Semiconductor	CodeWarrior™ Software Development Tools for DSP56800 (Metrowerks)
Software	CW568X	Freescale Semiconductor	CodeWarrior™ Development Studio for 56800/E Controllers With Processor Expert (Metrowerks)
Hardware	MC56F8300DSK	Freescale Semiconductor	56F8300 Developers Starter Kit
Hardware	56F800DEMO	Freescale Semiconductor	56F800 Demonstration Kit
Hardware	MC56F8367EVM	Freescale Semiconductor	Evaluation Module for 56F834x, 56F835x, 56F836x
Hardware	DEMO56F8013	Freescale Semiconductor	Demonstration kit for the 56F8013
Hardware	DEMO56F8014	Freescale Semiconductor	Demonstration kit for the 56F8014
Hardware	DSP56F801EVM	Freescale Semiconductor	Evaluation module for the DSP56F801 and DSP56F802

Disclaimer

This document may not include all the details necessary to completely develop this design. It is provided as a reference only and is intended to demonstrate the variety of applications for the device.

Notes

Learn More: Contact the Technical Information Center at +1-800-521-6274 or +1-480-768-2130.
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