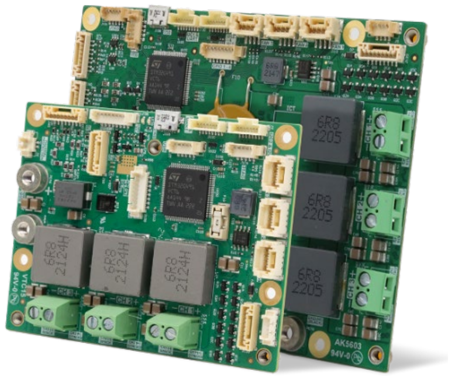
New High Performance TEC Controller Design



This white paper describes a new patented design of a TEC controller that delivers superior control of temperature stability and reduces power loss as well as other benefits. It features a novel bipolar DC drive circuit and control method that overcomes some of the limitations of current designs.

1. INTRODUCTION

A thermoelectric cooler or TEC is a solid-state heat pump. It is also known as Peltier device. When current flows through the device in one direction, heat flows or transfers from one surface to another, cooling one surface and heating the opposite surface. Reversing the direction of the current reverses the heat flow.

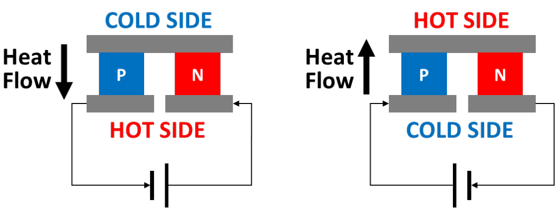


Fig. 1 Basic operation of TEC/Peltier

A typical configuration of a TEC-based temperature control system is as illustrated in Fig. 2, consisting of a TEC module connected to a TEC controller.

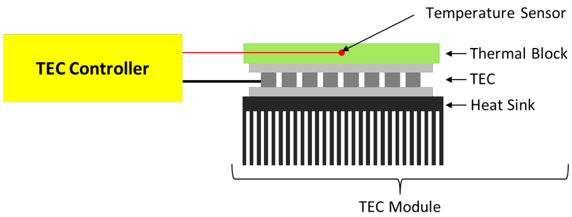


Fig. 2 TEC-based Temperature Control System

The TEC module provides the physical heating or cooling while the TEC controller modulates the current level and direction based on temperature sensor readings and the target temperature or temperature profile using close loop control.

Cooling and heating applications using TEC are used widely including consumer electronics, IT, telecommunication optical communication, medical, life science and industrial applications.

Different applications require varying levels of temperature control accuracy, precision and stability as well as different requirements for cooling/heating power, power efficiency and physical size.

2. CURRENT TEC CONTROLLER DESIGNS

There are several approaches taken in the design of TEC controllers to meet different needs.

Approach 1

Patented by Analog Technologies Inc, this uses one linear amplifier and one switch-mode amplifier (see Fig. 3) and a control scheme shown in Fig. 4A and 4B.

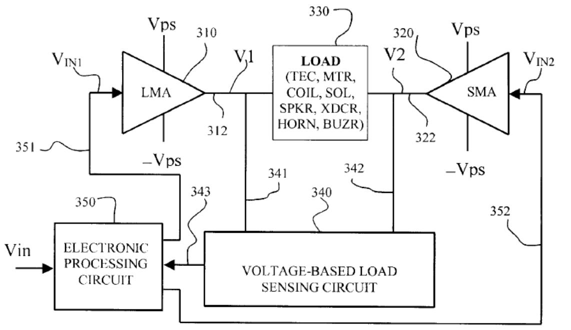
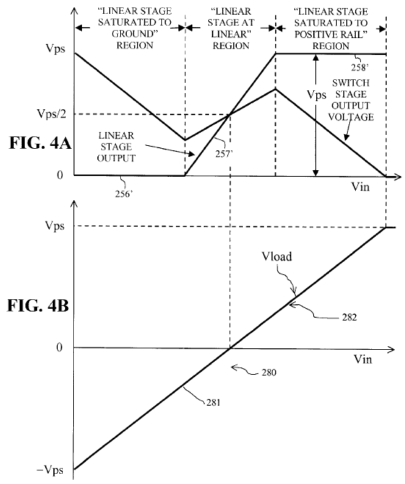


Fig. 3 One linear amplified and one switch-mode amplifier approach



It claims high efficiency but is very limited in the maximum output voltage (5V) and current (1A) thus confining it to low power applications only.

For higher power applications, various adaptations of the H-bridge have been used.

Approach 2

In its simplest form (see Fig. 5), the controller simply pulse width modulate the H-bridge to achieve different average voltage and polarity. However, TEC operate inefficiently in this manner because of excessive self-heating. This low-cost approach is usually reserved for where cooling inefficiency can be tolerated and where precision or stability are not critical.

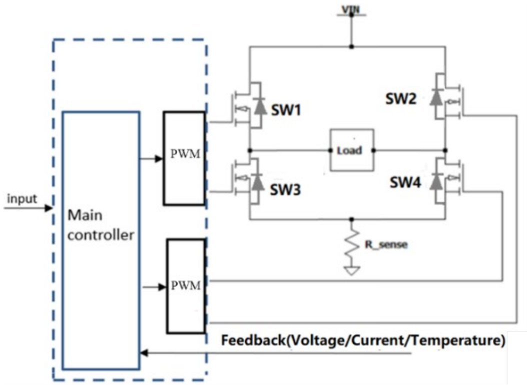


Fig. 5 Simple PWM H-bridge Approach

Approach 3

An improvement of the simple H-bridge is to generate the desired DC voltage and then use the H-bridge to control the direction to apply this DC voltage to the load as shown in Fig. 6. This reduces the current fluctuations on the TEC and thereby reduces self-heating. However, it is more costly to implement this approach and result in significant printed circuit board area due to the complexity of the circuit design.

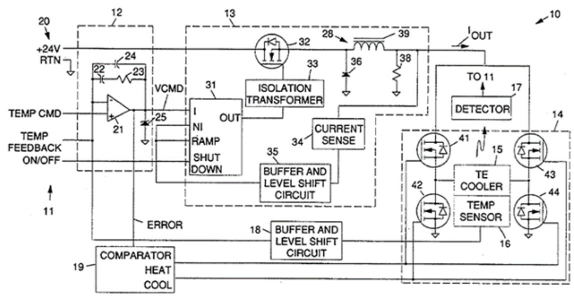


Fig. 6 Variable voltage with H-bridge approach

Approach 4

Another alternative method to reduce self-heating on the TEC is to add two buck converters between the TEC and the H-bridge as shown in Fig. 7.

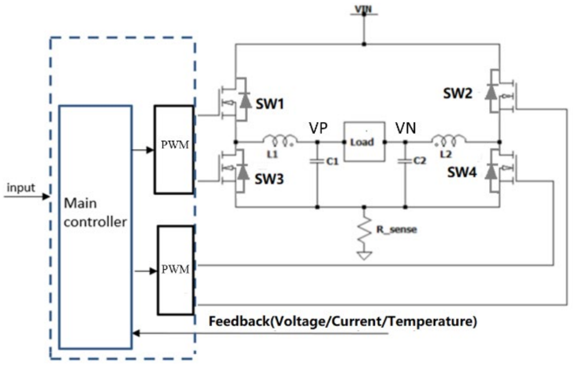


Fig. 7 H-bridge with buck converters approach

By varying the pulse width modulation for each half of the H-bridge, the node voltage at each terminal of the load (TEC) can be varied according to the control scheme in Fig. 8 to achieve different voltage and polarity across the load. Each half of the H-bridge and its corresponding buck converter essentially function as a variable DC source. While this approach is less complex than approach 3, it still requires significant circuit board area due to the inclusion of two large inductors of the buck converters.

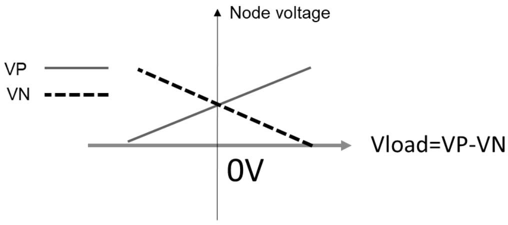


Fig. 8 Control scheme for circuit in Fig. 7

3. NEW TEC CONTROLLER DESIGN

We have a new adaptation of the H-bridge that have a number of advantages over the current adaptations described above. This new and patented design is shown in Fig. 9.

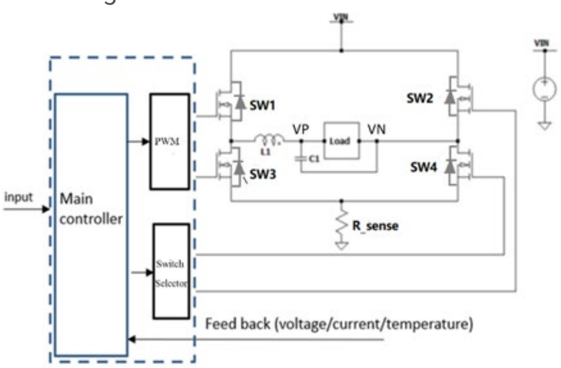


Fig. 9 New TEC controller design

It eliminates one buck converter of Approach 4 and changes the connection of the capacitor of the remaining buck converter. The right half of the H bridge is not pulse-width modulated but is controlled by a switch selector to select between the supply voltage or ground.

The control scheme is however more complex and is a non-linear one as depicted in Fig. 10.

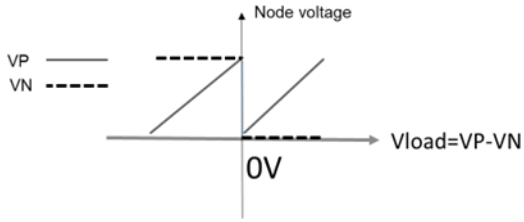


Fig. 10 Control scheme for new TEC controller design

4. BENEFITS OF NEW TEC CONTROLLER DESIGN

Power Efficiency Improvement

With one buck converter eliminated, inductor losses associated with that is also avoided. The change of the right half of H-bridge control from PWM to switch selector also removes switching losses there.

These power efficiency improvements of almost 50% have been proven in actual measurements of power efficiency of the new design versus the more conventional dual buck converter design.

	New Design	Conventional Design
Power Efficiency @ 50%	95%	92%
Power Efficiency @100%	98%	96%

Table 1. Power Efficiency Measurements

Temperature Stability Improvement

Higher temperature stability is achieved with the new TEC controller design as compared to conventional dual buck converter type TEC controller design largely because there is less fluctuation of voltage across the load due to the conversion of the right half of the H-bridge from PWM to switch selector control.

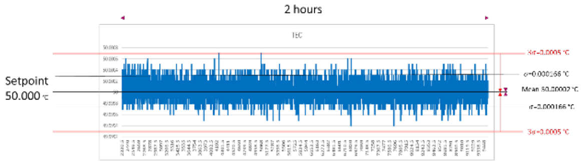


Fig. 11 Actual measurement of temperature stability over 2 hours

In actual measurement of the new TEC controller with a test TEC module over a two-hour period, the 3-sigma temperature variation of the load was well within ±0.0005°C. This is far better than comparable solutions available.

Size Improvement

With a simpler design and fewer parts, the new TEC controller can be designed with smaller printed circuit board area and also with the higher power efficiency, no heat sink is required. This results in a controller that is significantly smaller than existing solutions with comparable power handling and performance.

REFERENCES

1. Gang Liu, “High-efficiency H-bridge circuit using switched and linear stages”, U.S. Pat. No. 6,486,643.
2. Michael J. Ramirez and Joe A. Ortiz, “Thermoelectric cooler controller, thermal reference source and detector”, U.S. Pat. No. 5,450,727.
3. Chengge Fan, “Circuit arrangement and method of forming the same”, PCT/SG2021/050771.

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