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Application Note

Thermoelectric Assemblies for Medical Applications

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Thermoelectric Assemblies (TEAs) are the only effective thermal management solution for many medical applications. A wide range of small- and medium-sized heat pumping units handle most applications, including temperature regulation of samples and stabilization of sensitive instruments with the use of temperature controllers.

Because medical devices require strict temperature controls, TEAs offer precise temperature control with tolerances of +/- 0.1°C under steady-state conditions. DC operation with reverse polarity allows heating and cooling in thermal cycling applications, as well as rapid cool down to below ambient temperature.

Most medical applications have tight space constraints and low weight requirements. The units have fewer components and run on solid-state operation that yields high reliability and minimizes downtime of the medical device over its product life cycle.

TEAs are excellent choices for medical applications because they have low maintenance, are easy to repair, and environmentally friendly.

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Thermoelectric Assemblies for Medical Applications

Thermoelectric Assemblies (TEAs) are cooling and heating systems utilizing Thermoelectric Modules (TEMs) to transfer heat by air, conduction or liquid methods that include integrated temperature controllers. TEAs remove passive heat load generated by the ambient environment and active device in order to stabilize the temperature of sensitive components used in medical devices. TEAs are ideal because passive cooling technologies cannot go below ambient and compressor-based systems are too large to fit into tight geometric constraints of many medical instruments.

Medical Applications

TEAs are ideal for electrophoresis applications due to the ability to easily adjust temperature to either above or below ambient. This cannot be accomplished by any other means without a complex heating and cooling system. Other advantages include high reliability, maintenance-free operation, and compact size.

Optics used in laser systems can obtain peak performance by stabilizing temperature at or below ambient. TEAs dissipate heat generated by a CO2 or YAG laser that ranges from 15 to 100 watts. They can maintain the temperature of the laser system to within ±0.5°C, while the ambient condition may fluctuate from 20°C to 32°C. TEAs provide precise temperature control, compact size, heating, and cooling through reverse polarity and solid-state reliability.

TEAs maintain the control temperature of a reagent tub used in clinical diagnostic systems to 4°C to 6°C from an ambient temperature that can fluctuate from 23°C to 30°C. Heat load cooling requirements can range from 30 to 150 watts. TEAs are used due to tight geometric space constraints, low cost of ownership through solid-state construction and DC operation.

Digital radiography uses imaging systems with detector heads. TEAs cool the thermal output of the detector head to keep the temperature stable, while environmental temperature can range from 20°C to 38°C. This allows the detector to capture an image with very high resolution. TEAs also dramatically reduce the cooling noise vs. compressor-based systems.

Detectors used in MRIs obtain high-resolution images by controlling the temperature to a specific point, while the ambient temperature may fluctuate from 15°C to 38°C. TEAs are used in a closed-loop system with feedback to the temperature controller, removing 30 to 50 watts of heat at the source. They maintain the temperature of the detector to within ±0.25°C under steady-state conditions or offset control temperature from an ambient set point. Since passive cooling technologies cannot go below ambient, TEAs are ideal because they provide precise temperature control and low maintenance due to solid-state reliability.

In medical centrifuges, TEMs maintain the control temperature of the centrifuge tub to below 0°C from an ambient temperature up to 32°C. Heat load cooling requirements can range from 30 to 150 watts. TEAs are ideal due to tight geometric space constraints, solid-state construction, and DC operation.

Given the need for seamless mobility in a healthcare environment and battery requirements that need to last an entire 12-hour shift, TEMs allow portable medical cockpits to keep cool while meeting compact size constraints, low power consumption requirements, and low heat load.

Heat Dissipation

TEAs use TEMs to dissipate heat. TEMs are solid-state heat pumps that require a heat exchanger to dissipate heat utilizing the Peltier Effect. During operation, DC current flows through the TEMs and creates heat transfer and a temperature differential across the ceramic surfaces. Thus, one side of the TEM will be cold, while the other side is hot. A single-stage TEM can achieve temperature differentials of up to 70°C and can transfer heat at a rate of up to 150 watts. In order to increase the amount of heat pumping capacity, the TEM's modular design allows for the use of multiple TEMs mounted side-by-side, which is called a TE Array.

TEMs are composed of two ceramic substrates that serve as electrically insulating materials and house P-type and N-type semiconductor elements. Heat is absorbed at the cold junction by electrons as they pass from a low-energy level in the P-type element onto a higher energy level in the N-type element. At the hot junction, energy is expelled to a thermal sink as electrons move from a high energy element to a lower energy element.

Reversing the polarity changes the direction of heat transfer. TEMs are rated at maximum parameters (ΔT_{max}, I_{max}, V_{max}, and Q_{max}) under no load conditions, with temperature control accuracy achieving ±0.01°C under steady-state conditions. TEMs can be used as power generators and create 1 to 2 watts of energy per TEM. They can cool to -100°C (6-stage) and pump up to 150 watts of heat, with higher heat pumping capacities achieved by wiring TEMs into an array. Their geometry can vary from 2x2mm to 62x62mm and are much more efficient in heating mode than resistant heaters. They also fit into tight geometric space constraints that cannot accommodate a much larger compressor-based system.

Various Transfer Systems

Different TEAs are used to meet the thermal demands for specific applications.

- **Air-to-Air Assemblies** offer dependable, compact performance by cooling objects via convection. Heat is absorbed and dissipated by heat exchangers equipped with fans. Specifications apply to ambient temperature of 32°C and nominal voltage with tolerances ±10%.
- **Direct-to-Air Assemblies** offer dependable, compact performance by cooling objects via conduction. Heat is absorbed through a cold plate, pumping the heat through the TEM and dissipating it into the air through a heat sink. Specifications apply to an ambient temperature of 32°C and nominal voltage with tolerances ±10%.
- **Liquid-to-Air Assemblies** cool or heat liquids that flow through a heat exchanger. The liquid heat exchanger is designed for a re-circulating system, absorbs heat and pumps it through the TEM, where it dissipates into the outside environment through an air heat sink. Specifications apply to an ambient temperature of 32°C and nominal voltage with tolerances ±10%.
- **Direct-to-Liquid Assemblies** cool or heat objects attached directly to the cold plate. Heat is dissipated into a liquid heat exchanger on the hot side. The liquid circuit is normally a re-circulating type that requires a pump and additional liquid heat exchanger that dissipates heat into the ambient environment. Specifications apply to the warm side liquid temperature of 32°C and nominal voltage with tolerances ±10%.
- **Liquid-to-Liquid Assemblies** cool or heat liquids as they pass through a heat exchanger. Heat is then transferred onto another heat exchanger on the hot side. The liquid circuit is normally a re-circulating type that requires a pump and additional liquid heat exchanger that dissipates heat into the ambient environment. Specifications apply to warm side liquid temperature of 32°C and nominal voltage with tolerances ±10%.

Summary

Thermal management of medical electronic devices and systems is now more challenging. Power densities continue to increase while product form factors continue to shrink. Simple thermal management solutions, such as passive cooling (adding a fan and heat sink), are no longer typically viable to meet required performance and reliability specifications. In today's complex medical operating environment, TEAs are necessary to provide precise temperature control via cooling and heating in a variety of modular platforms.

TEAs combine special benefits that make them the only effective solution for many medical thermal management applications by offering greater performance, higher reliability, and low cost of ownership. Their advanced capabilities are aided by new material technologies, thinner profiles, and automated assembly.

About Laird Technologies, Inc.

Laird Technologies designs and manufactures customized, performance-critical products for wireless and other advanced electronics applications.

The company is a global market leader in the design and supply of electromagnetic interference (EMI) shielding, thermal management products, mechanical actuation systems, signal integrity components, and wireless antennae solutions, as well as radio frequency (RF) modules and systems.

Custom products are supplied to all sectors of the electronics industry including the handset, telecommunications, data transfer and information technology, automotive, aerospace, defense, consumer, medical, and industrial markets.

Laird Technologies, a unit of Laird PLC, employs over 10,000 employees in more than 39 facilities located in 13 countries.

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