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Thermoelectric Assemblies and Modules for Telecommunication Applications

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Application Note

Thermoelectrics are easy-to-service, cost-effective systems that encompass high cooling capacity in small sizes. With a wide range of small- and medium-sized units, Thermoelectric Assemblies (TEAs) and Thermoelectric Modules (TEMs) are the only effective thermal management solution for many telecommunication applications.

Many telecommunication applications have tight space constraints and low weight requirements, making thermoelectrics a better choice than compressor-based systems. In addition, the assemblies have fewer moving parts and require less maintenance over the extended product life cycle.

Thermoelectrics offer the ability to cool down to well below room temperature, DC operation with reverse polarity to accommodate heating and cooling in one system, and are easily optimized to minimize vibration and noise.

These devices can also be customized to accommodate equipment standards put in place to minimize signal, power, and equipment degradation. All of these factors, as well as being environmentally friendly and low-cost, make thermoelectrics an excellent choice for telecommunication applications.

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Thermoelectric Assemblies and Modules for Telecommunication Applications

Thermoelectric Assemblies (TEAs) are cooling and heating systems that utilize Thermoelectric Modules (TEMs) to transfer heat by air, liquid or conduction methods including integrated temperature controls. TEAs remove the passive heat load generated by the ambient environment and active device in order to stabilize the temperature of sensitive components used in telecommunication applications. TEAs are ideal because they offer higher efficiency than compressor-based systems.

Thermoelectric Operation

TEAs use TEMs to pump 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 TEM to create heat transfer and a temperature differential across the ceramic surfaces, causing one side of the TEM to be cold, while the other side is hot. A single-stage TEM can achieve temperature differentials of up to 70°C and 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.

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Thermoelectric Modules

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

- **Standard Modules** offer reliable cooling capacity in the range of 10 to 100 watts. They have a wide product breadth that is available in numerous heat pumping capacities, geometric shapes, and input power ranges. These modules are designed for higher current and larger heat pumping applications with a maximum operating temperature of 80°C.
- **Miniature Modules** have a geometric footprint less than 13x13mm and are used in applications that have lower cooling requirements of less than 10 watts. These modules offer several surface finishing options, such as metallization or pre-tinning to allow for soldering between TEM and mating conduction surfaces.
- **Multistage (Cascade) Modules** offer the highest temperature differential, (ΔT). Each stage is stacked one on top of another, creating a multistage module. Available in numerous temperature differentials and geometric shapes, these modules are designed for higher current and lower heat pumping applications.
- **Thermal Cycling Modules** are designed to operate in thermal cycling conditions that require reliable performance in both heating and cooling mode (reverse polarity). Thermal stresses generated in these applications will cause standard modules to fatigue over time. These modules are designed for higher current and higher heat pumping applications with a maximum operating temperature of 175°C.
- **High Power Density Modules** offer the highest heat pumping capacity within a surface area. Heat pumping densities of up to 14 W/cm^2, or twice as high as standard modules, can be achieved. The cooling capacity can range from 100 to 300 watts. TEMs are also ideal for applications that require low temperature differentials and high coefficient of performance (COP).

Thermoelectric Assembly 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 the ambient temperature and nominal voltage with tolerances ±10%.

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- **Direct-to-Air Assemblies** offer dependable, compact performance by cooling objects via conduction. Heat is transferred through a 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 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 or into water. 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%.
- **Re-Circulating Chillers** cool a wide range of liquid circuits and work in “closed loop” systems that contain a liquid-to-air assembly, pump, temperature controller, power supply and reservoir. Outlet temperature can be controlled from 2°C to 40°C to within ± 0.02°C under steady-state conditions using distilled H_2O as coolant.

Telecommunication Applications

TEAs and TEMs are ideal for telecommunication applications due to the ability to easily control 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 through solid-state operation, minimal maintenance, compact size, and installation in any orientation.

For example, laser diodes use TEMs to maintain the temperature of sensitive optical components to within ± 0.1°C under steady-state conditions. The laser diodes generate a signal that operates at a specific wavelength across long distances. The device requires active cooling to keep the optics functioning at peak performance, resulting in stable signal transmission. TEMs

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are an ideal solution because they do not require a heat sink and a fan to dissipate heat through the laser diode package, thus meeting compact size and noise constraints.

Also, laser pump diodes are used to amplify the signal of the laser diodes, keeping the signal transmission stable across long distances. In order to maintain a stable signal, the temperature of the laser pump diode needs to be precisely controlled in ambient temperatures. TEMs provide thermal stabilization through low maintenance, solid-state reliability, and precise temperature control at various ambient temperatures; all very important factors due the long service life of the laser pump diodes. A longer service life of the TEM reduces the overall operating and replacement costs of the equipment.

Other telecommunication equipment such as cable television (CATV) laser diodes utilize TEMs for temperature stabilization. CATV laser diodes are used to relay the signal between points in a CATV network. A CATV network transmits a variety of signals with any number of channels downstream in the system to the consumer subscribers on that network. As technology has progressed, and as cable providers have included Internet capabilities into their services, upstream is also possible. As the temperature of the CATV laser diode increases, the signal deteriorates. Because of space constraints and a long service life, TEMs offer an excellent solution by providing precise temperature control through cost-effective, solid-state construction; reducing the overall cost to the unit.

Avalanche photodiodes (ADPs) are another telecommunication application that incorporate TEMs into their design for keeping the device at a target temperature. ADPs are extremely sensitive devices used in data transmission for receiving excessively weak signals in high-speed sensitive receivers. The compact size and low noise of the TEMs contribute to the ability of the ADPs in transferring large amounts of data over long distances. The temperature the device is operating at determines how much data can be transferred. With a long service life, TEMs keep the device operating at the target temperature, allowing for a higher data transfer rate. TEMs also reduce thermal noise, which limits the disruption of the signal, allowing the ADP to operate at optimal performance.

TEMs are also utilized by GPS backup cellular networks for precise temperature control. GPS backup cellular networks use crystal oscillators to track time in case of a power outage. TEMs keep the crystal oscillators resonating at room temperature in order to maintain a stable signal at the target frequency. They slow down resonating, causing signal degradation, when the temperature either increases or decreases from room temperature. TEMs are an ideal heating and cooling solution in very tight space constraints because they provide high power efficiency and emit no noxious gases.

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A final telecommunications application that incorporates thermoelectric technology is base stations. Base stations use TEAs to actively cool the cabinet enclosures of Battery Backup Unit (BBU) systems. Base stations use BBUs as emergency power sources when primary power is lost. System service life of up to 20 years is expected and battery life degrades rapidly in high temperature environments. The heat load requirements are dependant upon the number of batteries used. TEAs lower the site's total cost of ownership by minimizing the frequency of servicing and replacing the batteries in the field and by reducing the operating cost through low power consumption, low maintenance, and high reliability.

Summary

Thermal management of telecommunication electronic components and systems is more challenging than ever. Power densities continue to increase, while product form factors continue to shrink. Simple thermal management solutions, such as adding a fan or heat sink, are no longer typically viable to meet required performance and reliability specifications. In today's complex telecommunication operating environment, TEAs and TEMs are necessary to provide precise temperature control in a variety of modular platforms.

TEAs and TEMs combine special benefits that make them the only effective solution for many telecommunication thermal management applications by offering greater performance, higher reliability, and longer life. Their advanced capabilities are aided by new materials technology, thinner profile modules, 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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