Automotive Thermal Management

In terms of automotive engineering design, key design considerations in the worldwide automotive sector are emissions legislation for internal combustion/ electric/ hybrid vehicle developments together with the increasing use of electronics in vehicle management systems.

Miniturisation and multifunction electronic design for the future

Electronic designs are providing more functions than ever before. To reduce emissions, design engineers must consider reduction in weight and size and improved aerodynamics of the vehicle amongst other design requirements. Electric vehicle batteries have a larger footprint than internal combustion engines, therefore any reduction in footprint, both physical and carbon, is a vital consideration for the future.

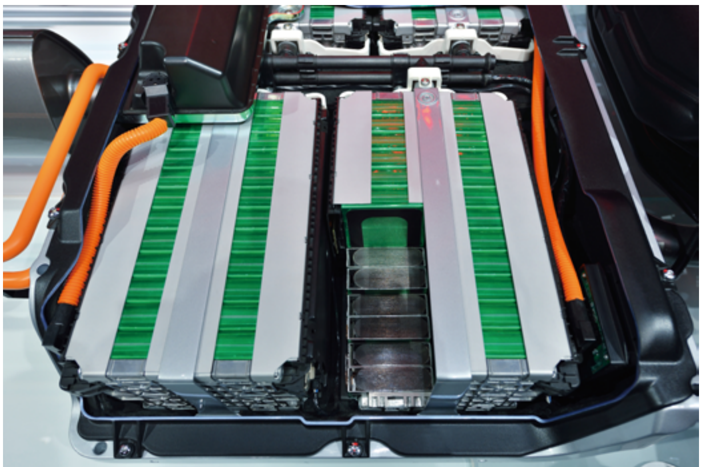

Electric vehicles using charging infrastructure

Managing heat loss to ensure electronic design performance

In automotive design as with all mechanical and electronic systems an inevitable amount of energy is lost as heat and this can lead to issues in device and system perfomance of the individual electronic components as well as in vehicle lifetime control.

Hot-spots

In battery design, as well as in electronic circuits, fast charging is a technological development that is influencing both the vehicle design and the infrastructure required to support this. Fast-charging of batteries can sometimes lead to hot spots developing in battery cells.


Electric vehicle battery cells in an array

Dendritic growth development

Alternatively, within battery cells, dendritic growth development within cold electrolytes can also be problematic as they may penetrate and pierce the cell lining.

Fluctuating temperatures

Excessive environmental temperatures need to be controlled to enable optimal performance.

Thermal management features significantly in all these areas in terms of both passive and active systems.

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Intelligent Thermal Management

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Active thermal management with thermoelectrics

Thermoelectric devices are small, light solid-state devices, effective for active, precise temperature control. These can be used both in embedded electronic system design as well as to provide active cooling to larger spaces.

Thermoelectric cooling devices and thermoelectric fan assemblies offer solutions to active climate management which enable:

- targetted, zonal local cooling and heating, for example for passenger comfort
- cooling of electronic components below the surrounding ambient temperature
- very stable temperatures, using their ability to both rapidly cool and heat in a single unit

Lithium ion battery temperature stability

Electric vehicle batteries perform best at room temperature (approx. 20°C). Operating above this temperature reduces a lithium ion battery's life. Charging points also benefit from temperature control due to ever changing external environmental conditions.

Thermoelectric cooling is useful to provide optimal operational temperature conditions for electric vehicle batteries and charging points.

Providing Zonal Passenger Comfort

Localised, zonal cooling/heating can be integrated into the seating area of a vehicle for passenger comfort by providing targeted temperature control of the seats, steering wheel, door panels and ceiling panels where required by the passenger. This is more efficient use of passenger comfort mechanisms due to its zonal nature resulting in a greatly reduced air-conditioning output power compared to traditional air conditioning systems and also has the added advantage of being light and small form-factor.


Adaptive® thermoelectric assemblies

The technology - thermoelectric assemblies

Thermoelectric assemblies consist of a thermoelectric module and the surrounding thermal system. The thermoelectric cooler (TEC) module pumps heat energy from a cold side to a hot side, against the temperature gradient. The thermal system can include interfacing the module with air (e.g. heat sinks and fans), metal plates or water (liquid cooled plate).

Thermoelectric assemblies are an additional method to pull more heat energy out of a component above the ambient temperature where the main barrier to cooling is the initial heat transfer from the device/component.

Thermoelectric assemblies provide these properties whilst
- being robust with very few moving parts (e.g. fan)
- having a long life

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- having invulnerability to leaks
- working in multiple orientations
- possessing a compact size and weight
- being modular: efficiency remains consistent irrelevant of size. Power pumped is proportional to size.
- 19-400W cooling range
- operating at a broad spectrum of temperatures -40 to 70 degrees C with maximum temperature difference of 45-55 degrees C.

Thermal inteface materials - providing seamless heat transfer

Passive Thermal Management

The increasing use of electronics in vehicle management systems means that excess heat is an issue which affects device performance.

Here, thermal management via passive cooling using a combination of thermal interface material, heat pipes, heat sinks, vapour phase plates and liquid cooling is effective.

What's new in Electronics Thermal Management

The trend for thermal management of embedded designs is for the use of PCM (phase change material) interface products instead of thermal grease/putty. The PCM is usually in the form of a paste that can be printed or dispensed onto a surface in order to fill very small spaces. When a stated temperature is applied, then the PCM will change phase and flow, filling air gaps and voids with a thermally conductive material allowing for effective dispersal of heat through the system. These materials are most effective to fill gaps of less than 0.1mm

Diagram 1

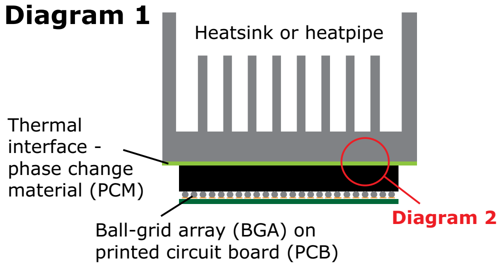
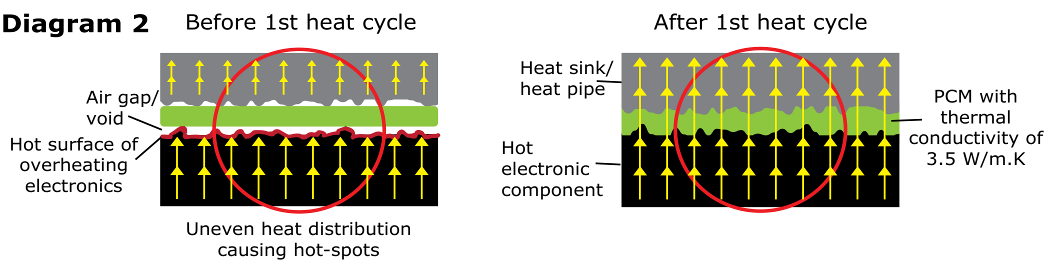


Diagram 2



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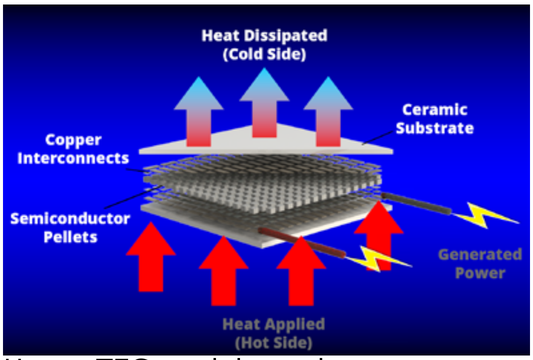
Providing Ultra-low Power to Sensors



How a TEG module works

If there is a consistent source of waste heat in a system design, this may be harnessed to provide ultra-low power via a thermoelectric generator (TEG). This energy is then used to power sensors and other low power devices in hazardous or remote areas, as an alternative to cabling or batteries. Like TECs, TEGs require virtually no maintenance and are small and lightweight.

A typical thermoelectric TEG module is shown in the image to the right, consisting of a number of pillars of a special thermoelectric material such as bismuth telluride, attached to electrical contacts and sandwiched between two ceramic plates. TEGs and TECs (cooling modules) are constructed in much the same way except TEGs have special high temperature solder, so they can operate in higher temperatures.

TEGs have a number of advantages

- Noise free
- Maintenance-free
- Reliable due to the fact they have no moving parts (long life times)
- Small and lightweight, with highly modular design
- Able to operate in any orientation, and high accelerations
- Able to generate power and also heat or cool
- Able to operate under a wide temperature range, including transients
- Environmentally friendly and safe

Thermoelectric generators also have significant potential for recovering electrical energy from the large quantity of waste heat present in the exhaust gases with power generated reaching up to 400W.

Disruptive technology

Continuous development work is essential for suppliers to continue to meet the technological demands of the sector. European Thermodynamics has active research programmes into lower cost thermoelectric materials, capable of operating at higher temperatures with the intention of lowering costs for future integration into vehicles and improving overall climate control systems.

European Thermodynamics Ltd is involved in automotive-based collaborative research and development projects in both the UK and EU (Horizon 2020).

Current automotive projects include:
DUET - Heavy duty, dual fuel, demonstrator engine achieving future EU emissions compliance with 23% carbon reduction
Viper2 project – Re-examining the use of thermal energy in engine management
Jospel project - A novel energy efficient EV climate system

Sister company DKNTec (dkntec.com) has developed a specific chemistry for the surface temperature heating of battery pack geometries, for use in cold climates. In the form a sprayed or silk-screened layer, typical 10 micron surface thicknesses are applied as an Ohmic coating that when powered, precisely maintains a set surface temperature, keeping the electrolytic fluid and battery skins at their optimum temperature, resulting in improved and safe battery charging.

Best practice for electronics thermal management in automotive design

The engineering team at European Thermodaynamics have come across a number of common issues when working with automotive design engineers and have a few easy guidelines to consider when thinking about localised climate control or over-heating of electronics.

✗ Never leave thermal management as the last consideration within a new design development program, as it could greatly reduce the performance of the final product and increase final system cost.

✓ Consider the best possible interface.

In order to provide effective heat transfer from hot spot to safe environment consider using an interface product between electronics PCB and a heat transfer medium (heat sink or heat pipe). Thermal interface materials provide an efficient method of contact so there are no air-gaps/voids in the transfer of heat.

✗ The most expensive option is not always the best. Graphite sheets may give excellent thermal conductivity but if there are air voids a phase change material or liquid-based thermoelectric assembly may provide better contact.

✓ Evaluate what available contact pressure there is

- (Dispensed) Paste / putty / pad / grease?
- Thermal spreading (anisotropic or isotropic?)
- Production method

✓ When designing thermal management systems, consider required efficiencies at component level, for example with a thermoelectric module electrical power in versus thermal power out.

✗ Do not run thermoelectric systems at full power. With thermoelectric climate control, running the TEC at full power will not achieve optimum results.

A high coefficient of performance (CoP) is desirable to reduce electricity usage and reduce the waste heat produced, but there is often a balance between efficiency and achievable pumping power or temperature difference.

Refer to technical reference document: Optimising Thermoelectric Cooler Modules in a System for more information.

For further information on thermoelectrics and thermal management for climate control and energy harvesting please visit www.europeanthermodynamics.com

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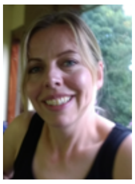
About the Author



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