Technical Article

How to Manage Coefficient of Thermal Expansion in Automotive Designs

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Coefficient of thermal expansion (CTE) is a way of describing how an object, material or liquid changes size with temperature. It's measured by calculating the percentage change in length of a material per degree change of temperature.

When heated, the molecules of a substance begin to vibrate and move away from each other, causing expansion; removing heat creates the opposite process. While all materials expand with temperature, they do so at different rates. This difference is fundamental in understanding mechanical designs when it comes to short- and long-term reliability.

The principles of CTE apply in various industries; they are perhaps most common in construction. Figure 1 illustrates gaps in construction material that allow for expansion and reduce the pressure that various materials exert on each other.

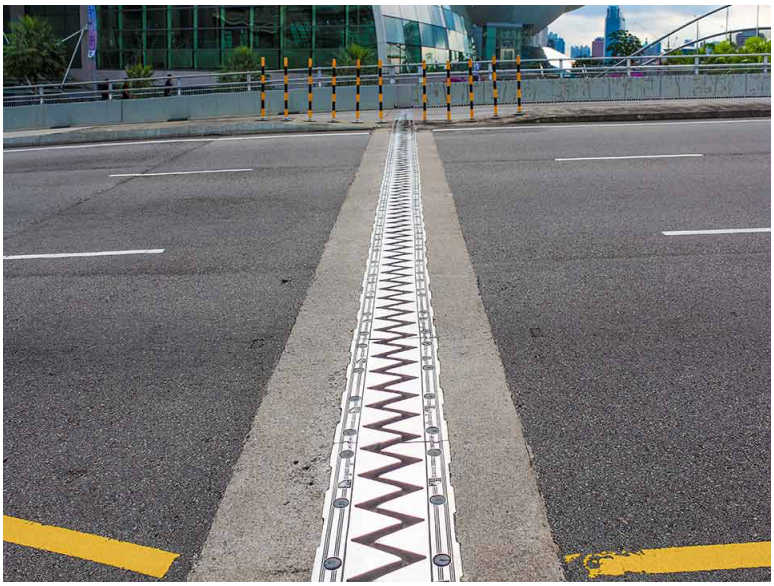

Figure 1. Expansion Joint on a Bridge in Order to Prevent Cracking

CTE in Automotive Designs

Cars are especially susceptible to CTE, since they have to endure rapid changes in temperature in a short amount of time while withstanding high levels of vibration. Automotive designers need to consider various scenarios, from cold starting the system in temperatures as low as -40°C to rapid increases of temperature exceeding 100°C, or from starting at temperatures above 100°C and then cooling rapidly. These quick temperature changes cause the expansion and contraction of liquids and materials in the automobile, which applies stress on other materials and connections.

The greater the difference in CTE, the worse the problem, especially for materials that connect directly together. Electronic components are becoming an integral part of vehicle operation, from the electronic ignition to the sensors in the exhaust to the automatic safety systems. The reliability of these systems – both in the short and long term – is critical for a safe and proper operation.

It's All in the Package

When it comes to electronics, one of the most common CTE issues occurs around the solder joints –connections of electronic components to the printed circuit board (PCB). These joints experience pressure from both heat expansion and vibration. One way to overcome or at least minimize these issues is to choose the right electronic packaging.

While modern electronics have pushed for the integration of more components into smaller spaces to make designs more compact (and in doing so, increased the demand for leadless packaging), the removal of the legs (or leads) on the package increases its overall CTE. On a leaded package such as a thin-shrink small outline package (TSSOP), the legs form into a shape that act like a spring and are separated from the molding of the package. This means the package CTE more closely matches a typical PCB CTE, as illustrated in Figure 2. Less stress is applied to the solder connections due to small difference in the expansion and contraction.

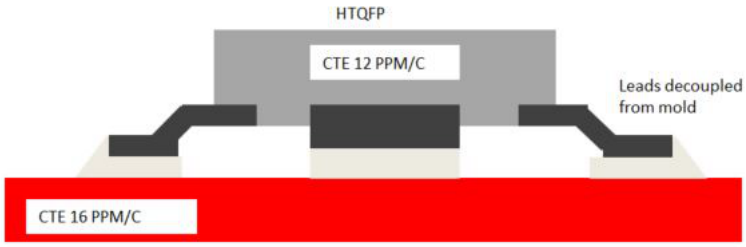

Figure 2. Typical Leaded Package CTE vs. Typical PCB CTE

Although the footprint of a component is bigger because of the legs, often this means a larger die attached pad (DAP) is possible. A larger DAP helps manage thermals that cause expansion, also improving the thermal footprint size and amount of copper that is need to dissipate the heat generated by a power supply, for example..

When considering DC/DC converters, if you optimize the architecture of the integrated circuit to support higher-frequency operation and a better phase margin, you can reduce the number of external components to compensate for the area taken by the legs. In most cases, the package is much smaller than the inductor or capacitor when combined as a total solution size. Thus, it is possible to offer the highest levels of size reduction without compromising reliability and quality simply by designing the integrated circuit to reduce the overall bill of materials and number of external passives. An example of this is TI's LM63625-Q1, developed specifically to minimize solution size without compromising the issues of CTE and vibration in the harsh environments of automotive systems.

With the right combination of circuit design and packaging, it is possible to manage various design challenges to create automobiles that people desire and that will remain reliable for many years.

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