Technical Application Report

Thermal Transfer Silicones in Automotive

Heat is the unwanted enemy in the development of many automotive electronic components. This unwanted heat can be generated by the component and further increased by its environment particularly if it is under the bonnet. The excess heat has to be dissipated away from the components to maintain performance and avoid premature failure of the component or device. This need for the efficient transfer of heat has become a key design requirement as components continue to reduce in size and increase in power, this is particularly apparent with microchip processors, LED's and power packs.

Designs will vary but in essence all involve some form of heat sink to dissipate the heat away from the active components. It is the interface between the heat sink and component that calls for the use of thermal transfer compounds, without their use any air gaps that exist will act as an insulator and prevent heat escaping. The benefits of using a heat transfer compound are shown in **Fig 1** and **Fig 2** below:

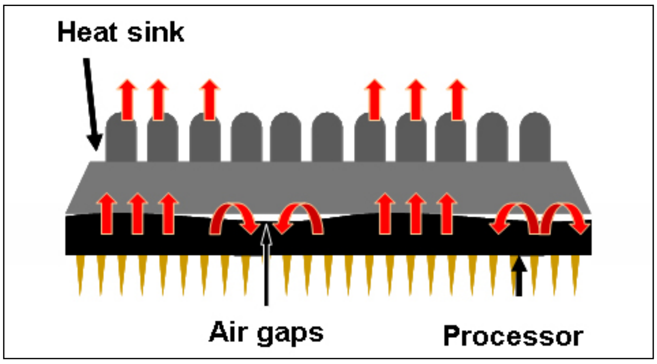

Fig 1 Showing insulating effect of air gaps.

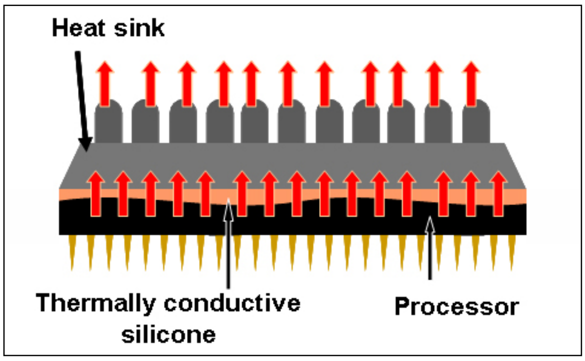

Fig 2 Showing improved thermal path to the heat sink

These transfer materials come in a wide variety of forms; liquid adhesives, pastes, gels, potting compounds, sheets, rolls, pads and sprays. They also utilise an equally large array of chemistries. Choice of material will be driven by a combination of factors including:

- Thermal requirements
- Manufacturing processes
- Environmental operating conditions
- Need for additional functionality

We will not endeavour to cover all the options available but will focus on the use of silicones as a base for manufacturing heat transfer compounds.

Why use Silicones?

Silicone polymers and elastomers have particular inherent physical properties including:

- Wide operating temperature range -115 to 300ºC
- Excellent electrical properties
- Flexibility
- Hardness range, soft gels to moderately hard rubbers
- UV resistance
- Good chemical resistance
- Resistant to humidity and water
- No or low toxicity
- Easy to use

These natural properties can be further enhanced using fillers and chemical additives to provide additional features when needed, including flame retardancy, thermal conductivity, electrical conductivity and adhesion. Through the selection of polymers and fillers it is also possible to adjust viscosity and rheology and the final hardness and modulus of the cured rubber. Control of the curing regime and speed can be achieved using the silicone chemistry to produce both heat and room temperature cure (RTV) systems. Silicones can be supplied as 1 or 2-part systems. In short silicone compounds are very versatile and provide design engineers with a wide product choice.

Types of Silicone Thermal Transfer Materials

In some engineer's minds thermal interface materials are limited in use to provide a simple bridge between heat sink and say a processor but they can provide much, much more in terms of functionality and offer tangible benefits as an integral part of component design. These silicone thermal transfer materials can be formulated in a variety of ways in order to produce three basic types of material; adhesive sealants, encapsulation/potting compounds and non-curing compounds. Opportunities are opened up to use one material to achieve two three functions as shown in the following example:

Typical example demonstrating the benefits if using silicone materials

A heavily populated PCB generates excessive heat which needs to be dissipated. The housing for the PCB is designed in aluminium to perform as a suitable heat sink. A simple schematic diagram is shown below **Fig3** and **Fig4**

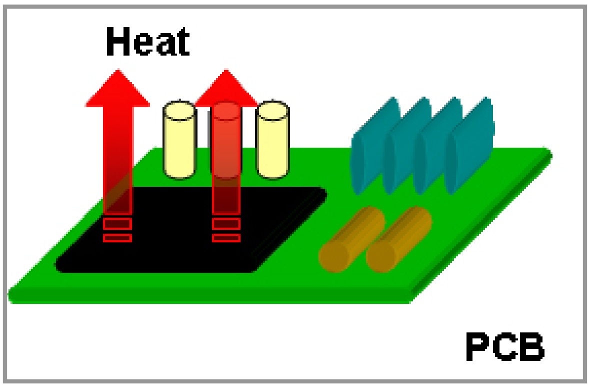

Fig 3: Populated PCB

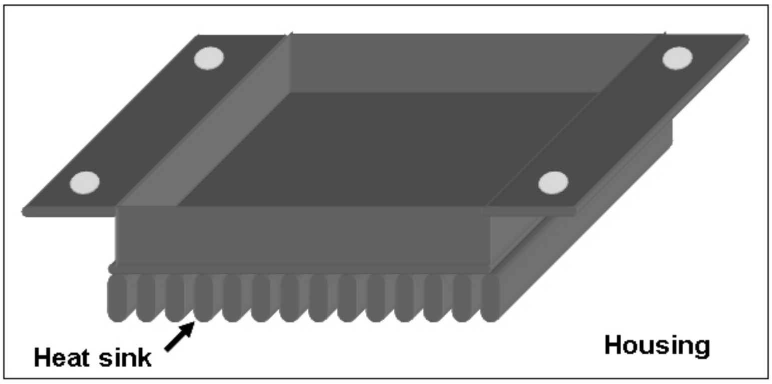

Fig 4: Housing with combined heat sink

The PCB needs to be secured within the housing and protected from moisture, vibration and the thermal stress caused by large thermal cycles. Housed close to the engine, any materials used must be capable of withstanding high operating temperatures say +200°C. All these functions could be achieved using just one silicone material such as 2-part silicone encapsulant with a low modulus which is either self bonding or can be used with a primer. See **Fig 5** and **Fig 6** Below

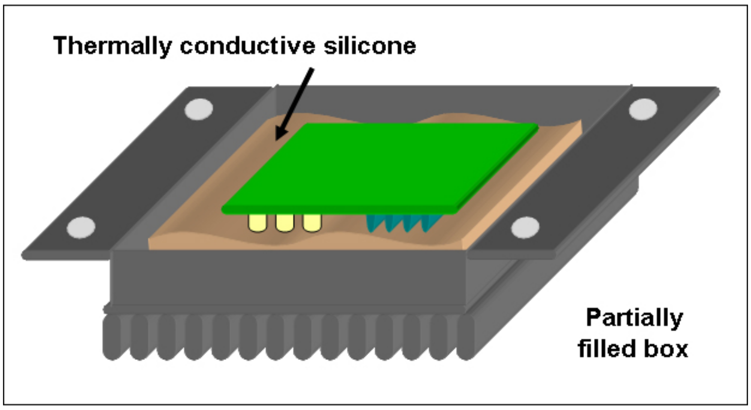

Fig 5 PCB held in place with silicone material

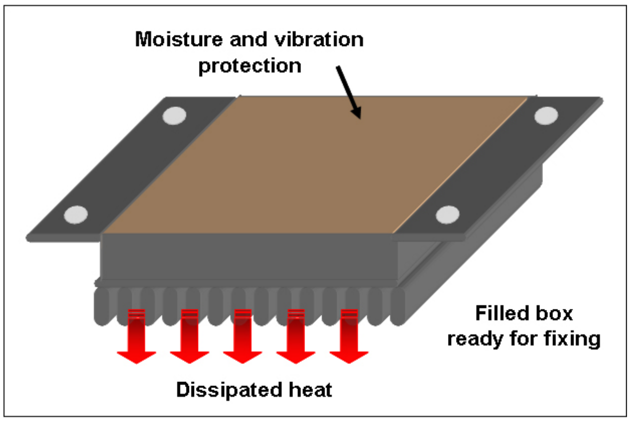

Fig 6: PCB fully encapsulated, providing a path for the heat and environmental protection.

Adhesive Sealants

The obvious benefits of having a thermally conductive adhesive enable you to permanently bond your component to some form of heat sink and eliminate the need for additional mechanical fixings. It will also prevent the possibility of movement and air gaps forming which will reduce performance. These products can also be used to form gaskets using FIPG (Formed In Place Gasket) techniques which will not only transfer heat but also form a seal against moisture and other environmental contaminants.

Using a flowable 1-part adhesive it is possible to apply a coating with thermal conductive properties. This approach has successfully been used to coat the back of LED lighting units and provide environmental protection and effectively remove heat from the diodes.

Encapsulation and potting compounds

Using a thermally conductive encapsulant has become a very attractive option when trying to remove heat from a number of components within a single device. Selection of a suitable flowable silicone will facilitate removal of all the air gaps in and around various components, thereby providing an effective path for the transmission of any unwanted heat. In addition to the dissipation of heat, silicone encapsulants will also provide protection from harsh environments, vibration and thermal shock.

Non-setting compounds

Silicone thermal transfer compounds are non-setting in that they do not cure, have no adhesion and retain their physical properties, similar to that of grease. The main reason to choose a compound rather than adhesive is the ability to easily rework the component. Under normal circumstances the component would be held in place with some form of mechanical fixing and the compound applied to simply improve heat dissipation. These silicone compounds are work stable and will with-stand reasonably high temperatures.

Silicone Chemistry

We will not go into too much detail regarding the chemistry but it is good to have a basic understanding when making the product selection. Two basic types of systems are used:

Condensation Cure

2-part encapsulants use tin based catalyst systems which cure at room temperature and cannot be accelerated with heat, they are robust and generally unaffected by contaminants.
1-part RTV adhesives are moisture cure systems which use a variety of crosslinkers to produce the cured elastomer. Each type of crosslinker will produce a chemical by-product during the curing process. Acetoxy crosslinker systems are not recommended for use within electronics as the by-product is corrosive acetic acid.

Addition Cure

Uses platinum based catalyst systems can be formulated to cure at room temperature or with heat, additional heat can be used to reduce cure times.

The platinum catalyst is susceptible to attack from certain chemical compounds which in turn will lead to inhibition of cure, resulting in a partially cured product. Bringing the uncured material into contact with the following chemical compounds should be avoided during the manufacturing process; nitrogen, sulphur, phosphorus, arsenic, organotin catalysts, PVC stabilizers; epoxy resin catalysts, sulphur vulcanised rubbers, and condensation cure silicone rubbers.

In 1-part addition cure adhesive sealants, cure will only start when heat is applied and in most cases it requires temperatures above 80ºC to cure the material, by elevating the temperature the cure speed will increase to a maximum temperature of approx 150ºC.

Adhesion is normally a little harder to achieve using these materials when compared with RTV's. Adhesion promoters are added to improve adhesion but these normally require the use of higher temperatures for slightly longer periods of time. For example, a typical adhesive may cure after 30 minutes at 100ºC while elevating the temperature to 150ºC for 30 minutes will ensure adequate adhesion to the substrate.

Measuring Thermal Conductivity

Heat can be transferred in 3 ways: Conduction, Convection and Radiation. As an aid to thermal management we are primarily concerned with the conduction of heat away from its source. Conduction of heat relies on the transfer of thermal energy by the vibration of particles which have physical contact with each other.

The units of measurement are; W/m K (watts per meter degree Kelvin)

Material	Value W/mK
Copper	400.00
Aluminium	300.00
Silicon	120.00 to 150.00
Aluminium + Epoxy	4.00
Plastics	1.00 to 10.00
Typical Standard Thermal Grease	0.50
FR4 (PCB Board)	0.30
Air	0.03

Fig 7 Typical values for thermal conductivity

Thermal conductivity can be measured in several ways. Three techniques are commonly used, in order of general usage these are; lees disk method, hot plate method and laser flash method. The Lees disk method has been shown over many years to be probably, the most consistent and direct method of measurement. This technique involves heating a sample between two metal blocks of known thermal conductivity until a steady state thermal equilibrium is reached. The top block is then removed and the rate of temperature decay in the lower block is measured over time. This is then plotted and the gradient f the curve is taken to calculate the thermal conductivity directly. (**see Fig 8 below**)

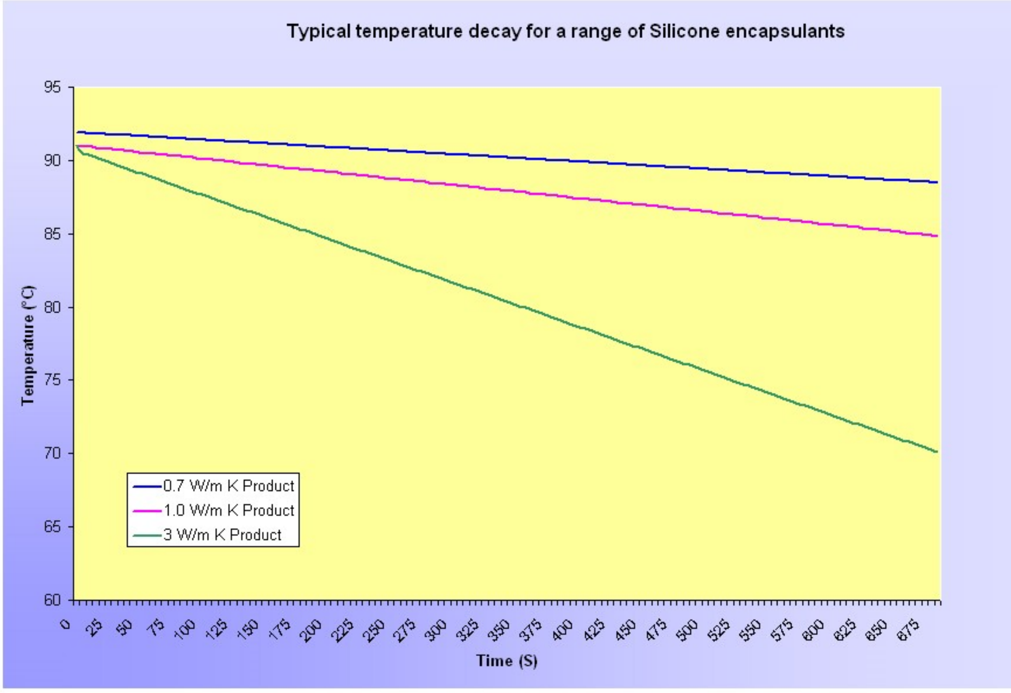

Fig 8 Graph showing thermal decay

Conclusion

It is clearly evident that meeting and satisfying the requirements for effective thermal management in modern automotive electronics is of not the sole prerogative of the electronics engineer. If a multidiscipline approach is used involving technicians experienced in electronics, production engineering and chemistry the rewards can be very significant. Advances can be made not only in terms of product performance but also in manufacturing efficiency which will result in overall cost savings and increased productivity.