EiceDRIVER™

High voltage gate drive IC

EiceDRIVER™ IC

Obtaining information about junction temperature by using the thermal coefficient $\Psi_{th(j\text{-}top)}$

Application Note

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Page or Item	Subjects (major changes since previous revision)

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1 Scope and product family

Calculating the junction temperature of power IC, such as gate drive IC, is an important design consideration. This application note gives an explanation of a datasheet parameter, which is called Ψ– (psi-) value and the way, how it is used. The advantage of using the Ψ–value is that the junction temperature can be calculated by simple measurements of the IC surface temperature and calculation of the power dissipation. Major dependencies are given, so that engineers are enabled to distinguish differences between various products.

This document applies to all EiceDRIVER™ IC products, which specify the Ψ–value.

2 Basics of thermal engineering for EiceDRIVER™ IC

The calculation of the junction temperature T_J of electronic components bases usually on measurements of physical values. These are the ambient temperature T_A and the temperature of the component on interest. The calculation is necessary as well. With these three data, one can use the well known equation

$$T_J = R_{th(j-a),tot} \cdot P_d + T_A \tag{1}$$

where $R_{th(j\text{-}a),tot}$ is the total thermal resistance from junction to ambient, P_D is the EiceDRIVER™ IC dissipation and T_A is the measured ambient temperature. The total resistance $R_{th(j\text{-}a),tot}$ can only be obtained by performing measurements, because the layout of the application, the way of mounting the PCB into the application and air flow inside the application influence strongly this value.

Two different paths of heat flow can be identified for IC packages according to a) in Figure 1: Firstly, the major one is usually over the leadframe and the pins. The die pad is often supported by one or even more pins for chip assembly reasons and those particular pins improve the heat flow into the PCB considerably and improve therefore also the heat flow to ambient. Secondly, a minor heat flow is via the IC surface, e.g. the top side, directly to the ambient air. This path is mainly depending on the convection conditions in the application. However, it contributes to the total thermal resistance junction to ambient. A third option of heat flow may be thermal radiation, but this is only a small influence and dominated by the two effects mentioned before.

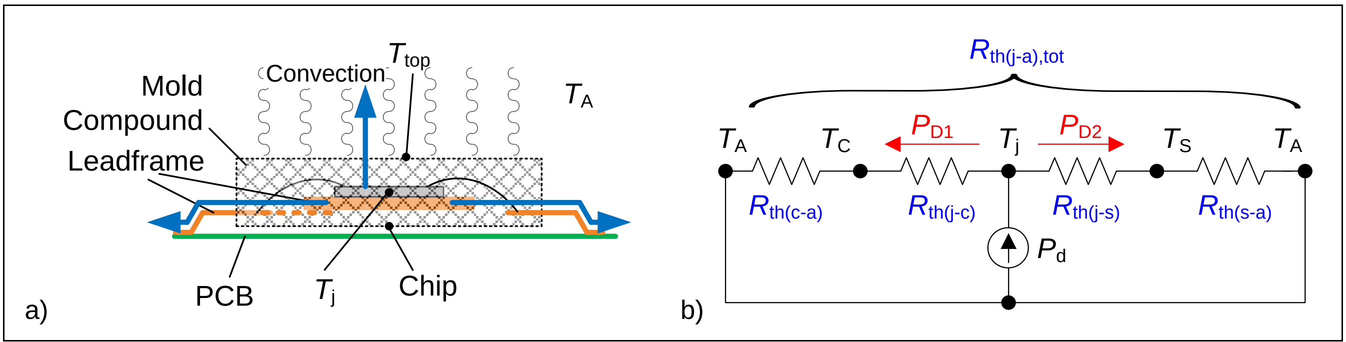

Figure 1 a) Cross section through an IC and package
b) Thermal equivalent circuit

The correlated thermal equivalent circuit is generally derived from this heat flow configuration and is shown in b) of Figure 1. Please note here, that one can change the individual portions of the total thermal resistance junction to ambient $R_{th(j\text{-}a),tot}$ by applying a heat sink to a IC´s surface and force the major heat to flow over this path. However, this option is not relevant for most applications, because creepage distances are usually much smaller and the PCB assembly process gets more complex.

The portion P_{D1} is much smaller than P_{D2}, because the thermal resistance from junction to the IC surface as well as from the IC surface to ambient are much bigger than from junction over the leadframe (i.e. “case”) to the PCB and further to ambient. That is plausible, because the mold compound is a bad thermal conductor, whereas the leadframe is often made with copper with a much better thermal conductivity.

3 Simplified thermal model

It is a widely spread method to take the surface temperature of EiceDRIVER™ IC or power transistors as a reference for the junction temperature. It is also easy to see, that the distance *d* from the chip surface to the package surface according to Figure 2 influences the heat flow as it is described in [1] and [2]. A longer distance will certainly lead to a larger temperature gradient from junction to the surface than a short distance. One has to consider that the power dissipation can be totally different, even though two different power IC have the same surface temperature. It is therefore important to know, that the surface temperature itself is meaningless without knowing the power dissipation and the package setup of the IC, when comparing two power IC.

The thermal model of section 2 is now modified in order to fit to the engineering method described above. We can now assume in good approximation, that the portion P_{D1} is zero and assume that all heat flows via the pins. The equivalent circuit simplifies then to the one given in b) of Figure 2. This would result in a directly measureable junction temperature on the surface of the IC. However, we know from the detailed thermal circuit that there is convection which leads to a slightly lower surface temperature.

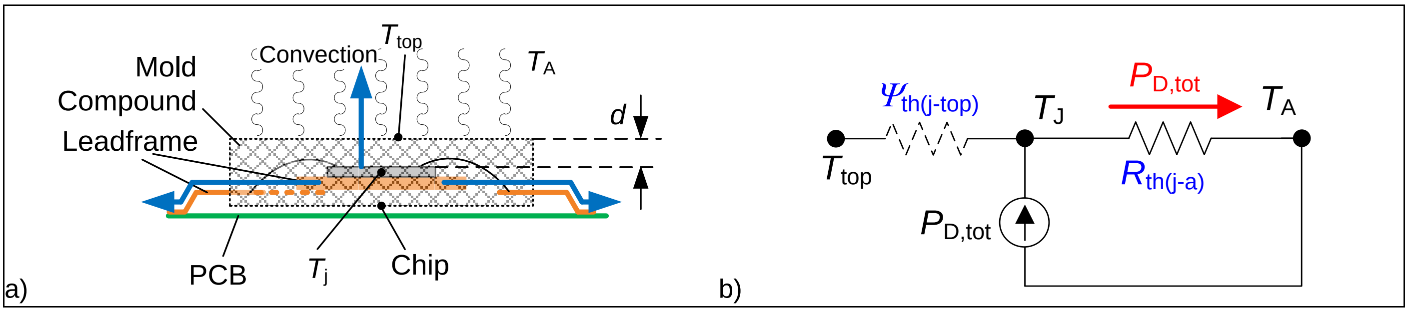

Figure 2 a) Cross section through an IC and package for simplified heat flow path
b) Thermal equivalent circuit simplified thermal equivalent circuit

There is a component given in dashed lines in b) of Figure 2 which represents the thermal coefficient psi (Ψ) junction-top $\Psi_{th(j\text{-}top)}$. This is not a thermal resistance in the physical way of understanding, because there is theoretically a priori no heat flow in this direction according to the thermal equivalent circuit in b) of Figure 2. The end of this path is open and not closed back to the power dissipation source in the equivalent circuit. Nevertheless, there is a relationship between the temperature of the specified point on the top surface of the package and the junction temperature. This relationship is similar as for the thermal resistances:

$$T_J = \psi_{th(j-top)} \cdot P_{d,tot} + T_{top} \tag{2}$$

It is now possible to determine the average junction temperature of the EiceDRIVER™ gate drive IC by performing a simple temperature measurement on the surface of the IC after a calculation of the power dissipation.

The thermal coefficient $\Psi_{th(j\text{-}top)}$ is given in the EiceDRIVER™ datasheets and considers natural convection by air. It is obtained by simulation and not verified by measurements. An optimized assembly of the application PCB can improve the EiceDRIVER™ IC cooling by using the air flow direction inside cabinets or by forced air.

4 Limitations of the simplified model

The simplified model has certainly some limitations. Amongst all, these are the most important ones:

- Ratio of heat flow by thermal conduction to PCB and by natural convection or correlation to application mounting conditions:
  One can support the thermal heat flow through the top side of the IC by gluing or clipping small heat sinks to the IC surface. This will certainly have effect on the resulting Ψ-value by making it larger.

- Temperature sensor attachment in case that measurement point is optically hidden:
  The temperature sensor needs a good thermal contact to the IC surface. Super-glue is often considered, but any layer of glue between the surface and the sensor corrupts the results. A large sensor which provides a good mechanical stability to press it onto the IC cannot be used. The rather large thermal capacitance acts as a heatsink.
  Best results may be obtained by using a thermocouple which is as thin as possible. The thermocouple can be pressed slightly onto the surface, while applying a tiny drop of super-glue. This may be supported by a small amount of thermal
  The infrared measurement technology overcomes all difficulties which are coming along with thermocouples. However, it is necessary to measure the thermal conditions in the application. It is mandatory, that the point of interest is optically visible and accessible for the infrared camera.

- Differences between simulation and application conditions concerning PCB layer setup.
  The PCB setup plays an important role. Especially the copper thickness of the directly connected layer contributes a lot to the overall heat sinking concept. A larger copper area at the pins, which support the leadframe or a thick copper layer improves the heat sinking of the EiceDRIVER™ IC. The PCB setup which is used for simulation of the Ψ-value can be seen in the datasheets using the Ψ-value.

References

[1] W. Frank, P. Türkes: A method for calculating the junction temperature based on temperature measurement on the mold compound; Proceedings of PCIM Europe 2006; Nuremberg, Germany, 2006.

[2] W. Frank, et al.: A new intelligent power module for home appliances; Proceedings of PCIM Europe 2009; Nuremberg, Germany, 2009.

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