Power Module Reliability

Solder-free and without base plate

The reliability of a power module is of vital importance to the user, who expects his system to work unimpaired throughout its entire service life. The elimination of the base plate offers clear design engineering advantages that boost system reliability. In fact, modules without a base plate can be expected to have an extended service life especially with respect to stress induced by passive thermal cycles.

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Conventional power modules feature solid copper base plates. This design concept brings about a number of disadvantages with regard to reliability. In most cases, the base plates are joined to the heat sink by way of screw connections at the corners or, in the case of larger modules, along the outer edges. In these cases, to ensure optimum heat transfer between base plate and heat sink in the centre region as well, the base plate has to be suitably deflected before mounting. However, the solder interface between the substrate and the base plate is a viscoplastic system, meaning the stresses are relieved due to plastic deformation. As a result, the deflection changes over time, so that an optimum geometrical shape cannot be achieved [1].

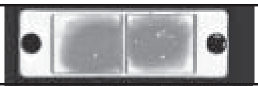
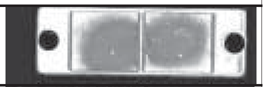
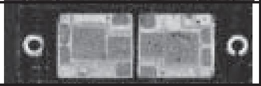
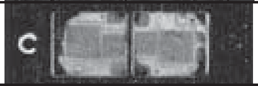
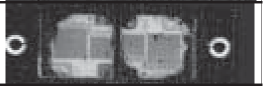
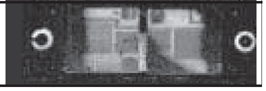
With base plate soldered	**INITIAL**	**After 150 temperature cycles (-40°C/+125°C)**	**After 200 temperature cycles (-40°C/+125°C)**
RoHS compliant SnAg(3.5)			
RoHS compliant SnAg(3.5)			
Lead solder SnPb(37)			
Lead solder SnPb(37)			

Figure 1: The effect of passive thermal cycles on conventional power modules with a copper base plate

The stress resulting from the different coefficients of thermal expansion of the base plate and substrate does not, however, only play a key role in manufacturing but also when the system is in operation. In application, a power module is exposed to significant temperature fluctuations. On the one hand, these thermal cycles are caused by the power loss produced in the power electronic component. These active thermal cycles are determined by the injected power loss and the thermal resistance of the module. Generally speaking, it is possible to reduce the temperature swing by enlarging the silicon area of the components, thus reducing the thermal resistance.

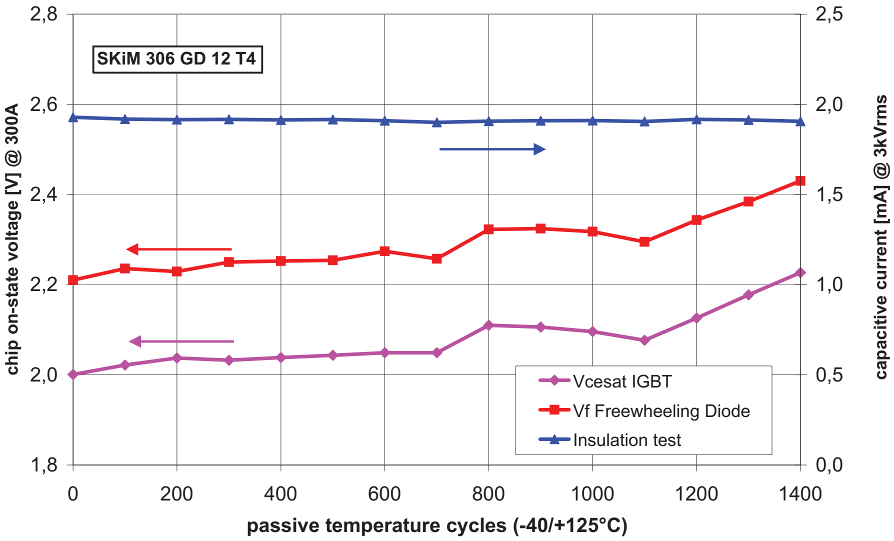


Figure 2: The result of an intermediate measurement of a passive thermal cycling test performed on a SKiM module

In the case of passive thermal cycles, by way of contrast, this is not possible. Passive cycles result from ambient temperature changes. For a power module, such stresses are caused by a temperature change in the heat sink which in turn may result from a change in the coolant temperature or from power losses in other components. The load cycling capability in the case of passive temperature swings is determined by the module design alone; it cannot be enhanced by increasing the silicon area.

The effect that passive thermal cycles have on conventional power modules with a copper base plate can be seen in Fig. 1. Owing to the different coefficients of thermal expansion of the base plate and the substrate, passive thermal cycles (-40°C/+125°C) result in such high stresses in the solder layer that delamination occurs in the solder interface after just 150 cycles. In the scanning acoustic microscope (SAM) images, this delamination is shown as light areas that spread from the edges of the substrate towards the centre. The strong reflection at this delamination means that barely any intensity is left to propagate into deeper layers. Thus, the images of the chip solder interface in the areas where this delamination occurs, show black marks. That said, this very artefact of the image allows for an evaluation of the development of this damage with regard to the chip position: in both solder systems (lead-free or lead-containing) after 200 cycles the damage has already propagated towards the chip position and interferes with the thermal path from chip to heat sink.

For modules without base plate, this failure mechanism is completely neutralised as there is no longer a firmly bonded connection on the substrate underside. Thus, power modules can be manufactured that are far superior to conventional power modules in terms of passive thermal cycling capability. Figure 2 shows the result of an intermediate measurement of a passive thermal cycling test performed on a SKiM module. In this module, the chip solder joints have been replaced by a more reliable silver die-attach layer [1]. In this test, the time-to-failure of six modules is to be investigated. Since the sintered connections are not expected to age, the purpose of the intermediate measurements is to monitor the chip blocking ability and the substrate dielectric properties. So far, the test revealed no signs of failure in the modules even after 1,400 thermal cycles.

Figure 3: SKiM is a 100% solder-free power module. The temperature cycling capability is fifteen times higher than standard soldered modules

Sources

[1] U.Scheuermann, P.Beckedahl: The Road to the Next Generation Power Module – 100% solder-free design, Proc. CIPS 2008, ETG-Fachbericht 111, 111-120, Nuremberg, 2008.

www.Semikron.com

Analogue Front-End for Accurate Metering

Microchip announces its next-generation Analogue Front End (AFE) for metering applications. The MCP3901 AFE features high-accuracy, dual 16-/24-bit Delta-Sigma Analogue-to-Digital Converters (ADCs) with up to 91dB Signal to Noise and Distortion (SINAD); internal Programmable Gain Amplifiers (PGAs) and voltage reference; phase-delay compensation; and a modulator output block, enabling more precise measurements than competitive solutions. With its unique feature set, high-speed sample rates up to 64kilosamples per second (ksps) and SPI interface, the MCP3901 AFE is ideal for a variety of single- and multi-phase metering, industrial and medical applications.

Integrated PGAs and a low-drift voltage reference enhance the MCP3901 AFE's ability to measure signals at very small levels, and reduce the number of external components needed. This enables smaller overall designs at lower costs. The phase-delay compensation block enables the MCP3901 AFE to compensate for differences in phase for three-phase energy-metering applications, while the SPI interface provides a simple connection to a microcontroller (MCU) and offers engineers more flexibility with their design. Additionally, through the SPI interface, designers can adjust the ADC over sampling ratio to control the resolution and sample rate as dictated by the needs of the application.

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Inductors Tackle Aerospace and Mil Applications

Coilcraft CPS (Critical Products and Services Group) has launched a new series of 0603-size ceramic inductors, targeting the aerospace and military markets. These robust components are manufactured to meet the special requirements of these demanding applications.

The Coilcraft CPS ML Series offers higher inductance values than other 0603 inductors, keeping board space to a minimum. Inductance values range from 47 nH – 22 ìH.

Q ratings are as high as 50 at 250MHz with Self Resonant Frequencies as high as 16 GHz. Ceramic construction provides high current handling, while a high-temperature encapsulant allows operation in ambient temperatures from -55°C to 155°C.

MTBF is 1 billion hours.

ML Series inductors are designed, manufactured and tested to ensure their suitability for mission-critical applications and for use in adverse environmental conditions.

COTS Plus, tin-silver-copper and tin-lead terminations are featured for long-term reliability. Additionally, components can be certified to meet specific customer requirements.

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