Why Is Cooling So Important For Magnetics?

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Cooling is crucial for magnetics and electronic components in general because it directly impacts their reliability and lifespan. In this article, we'll discuss the mean time between failure (MTBF) calculation, which is a key metric in assessing the reliability of electronic components, and explain how it can be applied to a magnetic component.

The mil standard MIL-HDBK-217F has been used for decades to calculate MTBF for different environments.

For this example, I will use the Ground, Mobile (G_M) environment for demonstration purposes. To calculate λ_p, the component failure rate per 10^6 hours, the standard provides the following equation:

$\lambda_\rho = \lambda_b * \pi_T * \pi_Q * \pi_E$

where

λ_b is the base failure rate for a transformer and is 0.049 (F/10^6) for power over 300 W

π_T is the temperature factor and is 3.1 for a hot spot of 130˚C

π_Q is the quality factor and is 1 for a MIL-SPEC type of transformer and

π_E is the environmental factor and is 12 for G_M. πE can vary from 0.50 for SF (Space Flight) to 610 for CL (Cannon Launch).

So, given the values specified above, the λ_ρ for this transformer is 1.8 total failures per million hours (FPMH). The MTBF then will be $1/\lambda_\rho$ = 555,000 hours for a transformer with a 130˚C hot spot working in a Ground, Mobile environment.

Payton designs start by knowing the thermal conditions of the application. We design based on a 130˚C hot spot internal to the planar magnetics with a max of 150˚C in some cases. After a prototype is built, we use thermal imaging to measure the hot spot temperature and confirm the design. An example is shown in the figure.

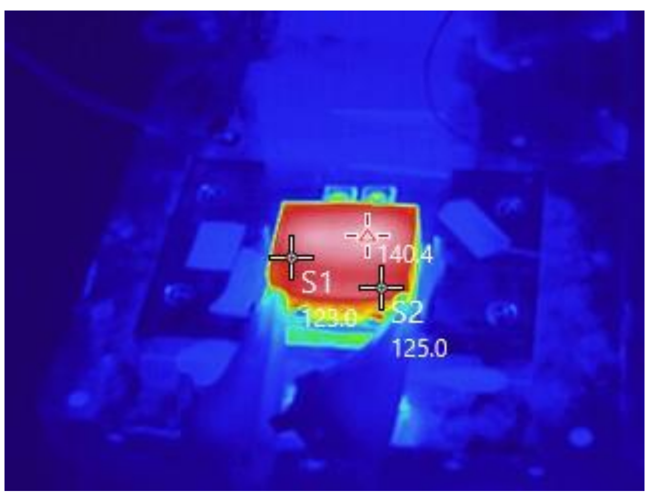

Figure. The hot spot temperature is a critical factor in determining component failure rate and MTBF of planar transformers. In this example, we measured a surface temperature of 140.4˚C on the transformer.

For example, a 12-kW planar transformer, mounted on a cold plate at 90˚C with a thermal impedance between heatsink and hot spot of 0.6˚C/W and 100 W of dissipation will yield a temp rise of 60˚C. This transformer will then operate with a 150°C hot spot. Applying the above equation for λ_p, that hot spot means the transformer will have with an MTBF of 485,000 hours in an automotive environment. That value corresponds to 55 years.

Efficient cooling methods, such as heat sinks, thermal management materials, and proper airflow, help dissipate heat and maintain components within their specified temperature ranges. This not only enhances the reliability of the components but also extends their operational lifespan, contributing to overall system reliability. In mission-critical applications like automotive environments, where reliability is paramount, understanding and managing thermal conditions become even more crucial.

Reference

"Military Handbook, Reliability Prediction Of Electronic Equipment, MIL-HDBK-217F," 2 December 1991, accessed on the Quanterion website.

About The Author

Jim Marinos is executive VP marketing and engineering for Payton America. Payton designs and manufactures custom planar magnetics from 5 W to 300 kW. Jim has been involved in the design and development of switch-mode power systems for DOD applications and magnetic designs since 1982. He received his electrical engineering degree from Pratt Institute.

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