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Design Flexibility of Extended Temperature Inductors

Abracon AMXLA-Q Molded Inductor Series

Gerald Capwell
Engineering Manager- Magnetics
Abracon, LLC

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Introduction

Anyone familiar with system design knows there are many different aspects that must be considered to create a product with stable operation in not only nominal conditions but also extreme conditions. Extreme conditions include stressors such as temperature, moisture and humidity, vibration, and shock. Thermal considerations are especially important when designing power systems that may experience wide environmental temperature fluctuations and/or inherent heat generated by load variations.

Abracon's new AMXLA-Q extended temperature inductors help relax design restrictions often placed on inductors within power systems thanks to their ultra-wide -55°C to +180°C operating temperature range. Moreover, the extended temperature inductors lend themselves to more exotic applications where extremely hot ambient temperatures are common. The AMXLA-Q devices are AEC-Q200 qualified for automotive applications but are also suitable for many harsh industrial applications.

This paper will review designing for an inductor's case temperature. Discussion will show how the AMXLA-Q extended temperature devices sustain performance in applications with elevated surrounding ambient temperatures or with increased Irms current operation. Finally, there will be an explanation of how extended temperature inductors require careful consideration of saturation current limitations.

Temperature Nonlinearity

Fig. 1. illustrates the general nonlinearity of the component's case temperature as a function of current. The case temperature comprises of the ambient temperature plus the temperature rise current, known as Irms.

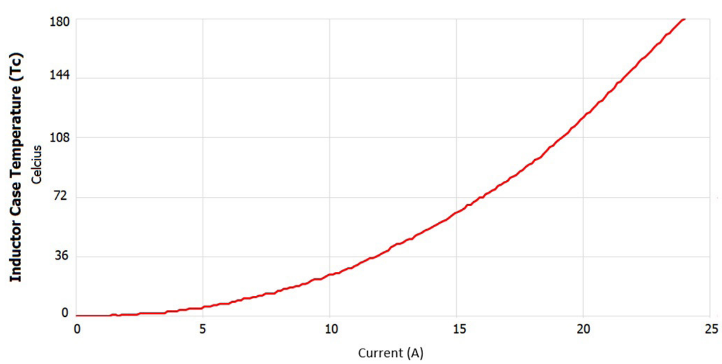

Fig. 1. Rise in Case Temperature as a Function of Current

As with any inductor, Irms is an important design parameter that tells the designer the change in case temperature as a function of the current running through the inductor. As current increases, the inductor experiences self-heating caused by the Irms current in association with AC (core) and DC (DCR) losses of the inductor material.

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Increased Ambient

Abracon specifies the maximum temperature rise (Tr) of the inductor as 40°C. Extended temperature inductors tolerate a maximum case temperature (Tc) of 180°C. Therefore, assuming a typical Δ40°C for Irms would allow a maximum ambient temperature of 140°C. This is illustrated in Fig. 2 below.

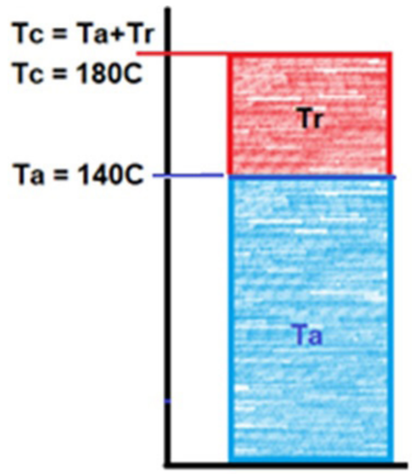

Fig 2. Design with Increased Ambient

Abracon datasheets specify maximum values for Irms based on a Δ40°C increase in temperature. Graphs including Irms are typical values. If the design requires an ambient higher than 140°C, then the Irms value must be derated to not exceed the maximum case temperature (Tc).

Increasing Irms

Another option for designing with extended temperature inductors is to maintain a low ambient temperature and to increase the maximum current of the inductor. For example, if the inductor is used in a system that supports active or passive cooling, then the ambient temperature surrounding the inductor can be maintained when increased performance is needed. Fig. 3 illustrates a low ambient temperature with much of the total case temperature produced by the temperature rise from self-heating.

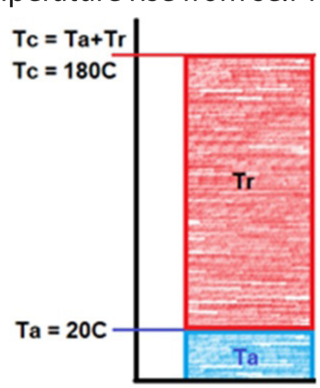

Fig 3. Design with increased current

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The designer must keep in mind the temperature curve is non-linear, and care must be taken if running the inductor at a high sustained current. Sustained currents will heat the device more than intermittent currents. Abracon recommends the overall sustained maximum current should not exceed the specifications shown in the datasheets.

Saturation Design Constraint

Designing with extended temperature inductors relaxes the Irms and ambient limitations but highlights the importance of another restricting inductor parameter, the saturation current (Isat). As current increases through an inductor, the material of the inductor loses its ability to store energy and therefore reduces overall inductance.

Fig 4. shows how an extended temperature inductor relaxes the restrictions on ambient temperature and extends the usable Irms current (16A as opposed to 13A). The limiting design factor now becomes the saturation current (Isat).

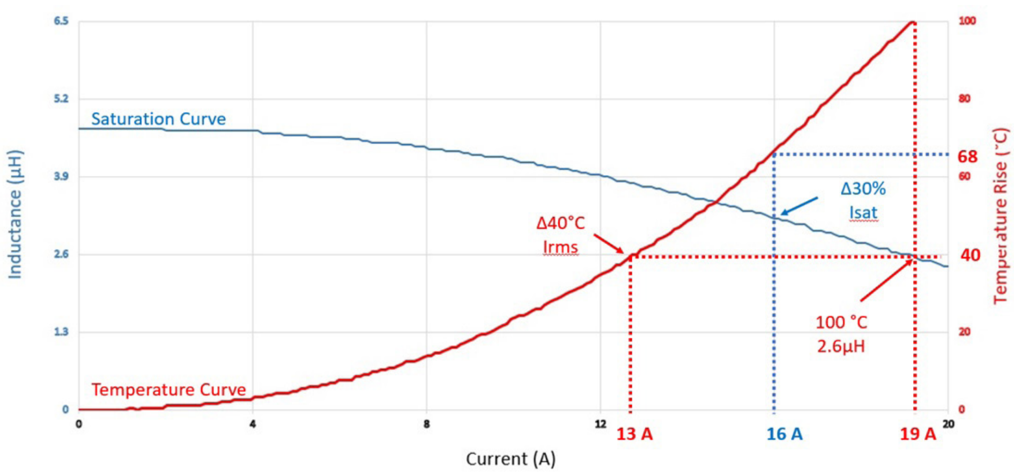

Fig 4. Example Irms and Isat graphs

The figure above shows the performance curves of a 4.7µH inductor and illustrates the Irms (red) curve along with the Isat (blue) curve. The Irms maximum is 100°C. At this temperature, the inductance reduces to approximately 2.6µH, or a 38% drop, and corresponds to approximately 19 amps of current through the inductor.

Abracon specifies the saturation current for the AMXLA-Q series as a ≤30% decrease in inductance. The 38% drop shown in Fig. 4 indicates the inductor is saturated, and the current will need to be reduced. The blue dashed lines show the point (16A) at which the inductor reaches its 30% saturation limit, corresponding to a +68°C increase in inductor case temperature. If designing to a 30% saturation limit, a 16A-rated Irms current through the inductor would be the maximum allowed. The maximum ambient temperature allowed would be 112°C (180°C - 68°C = 112°C).

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Conclusion

In summary, Abracon’s extended temperature inductors promote design flexibility. For example, power systems can be designed for more rugged environments where ambient temperature may vary considerably or in applications that simply require more thermal design margin. The AMXLA family also enables design flexibility for power systems which must respond to large and fast changes in load current. The extended temperature inductors can help alleviate some of the design constraints required in today’s complex systems.

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