RENCO ELECTRONICS, INC.

Power Inductors and Peak Current Handling Capability

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Abstract

As high tech electronic products and their power supplies continue to shrink in size the peak current handling capability of power inductors should be looked at closely by the design engineer. This paper discusses power inductors, peak current handling capability, and the basic formula used in properly designing an inductor to handle peak current.

Introduction

Design engineers are called upon on a daily basis to reduce the size of electronic products. This ultimately means that an attempt will be made to reduce the size of the inductor and/or transformer used in the power supply. Design Engineers have been able to reduce the size of inductors and transformers by increasing the frequency the magnetic components operate at.[1] However, there are times the increase in frequency is limited. If the peak current handling capability of inductors is understood perhaps the size of an inductor can be reduced further.

Peak Current Defined

When selecting inductors engineers have to ensure the inductor can handle the maximum peak current their circuit generates (See Figure 1). Therefore, inductors are rated to handle what is more commonly known in the magnetics world as Saturation Current (Isat). Saturation Current is the DC current that causes the inductance without current to drop, typically 10-20%, as a result of core saturation. In addition, saturation is the point when an inductor can no longer store energy and instead shows a drop in energy storage and inductance.

Peak Current $I_L PEAK = I_L AVE + ½ΔI_L$

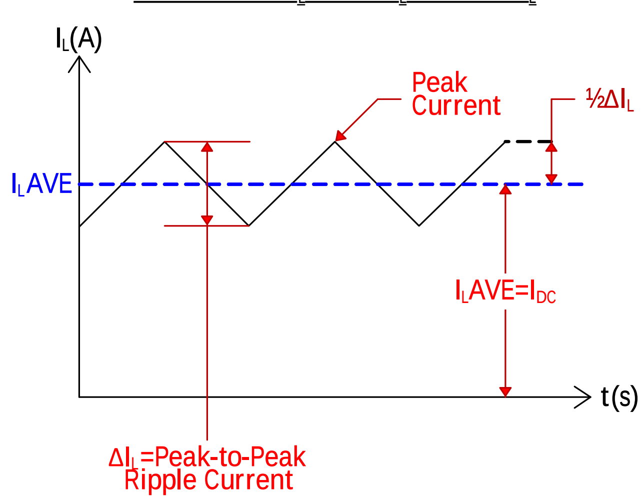

Figure 1 Inductor Current Waveform

From the inductor current waveform, in Figure 1, it is evident that the inductor peak current is the sum of the Average inductor current and half of the peak to peak ripple current.

It is worth mentioning that the Peak to Peak ripple current illustrated in Figure 1 is what causes core losses in inductors. This is an area of occasional confusion in the world of power supply design.[2]

Hard Saturation vs. Soft Saturation

When taking a closer look at how different materials used in power inductors saturate it becomes clear that some materials will saturate hard and other materials will saturate softly. Hard saturation is simply when the inductance abruptly drops once the Isat is reached. Some would say hard saturation is like something falling off a cliff. Soft saturation is simply a gradual drop in inductance. The saturation graph in Figure 2 clearly illustrates the difference between hard and soft saturation.

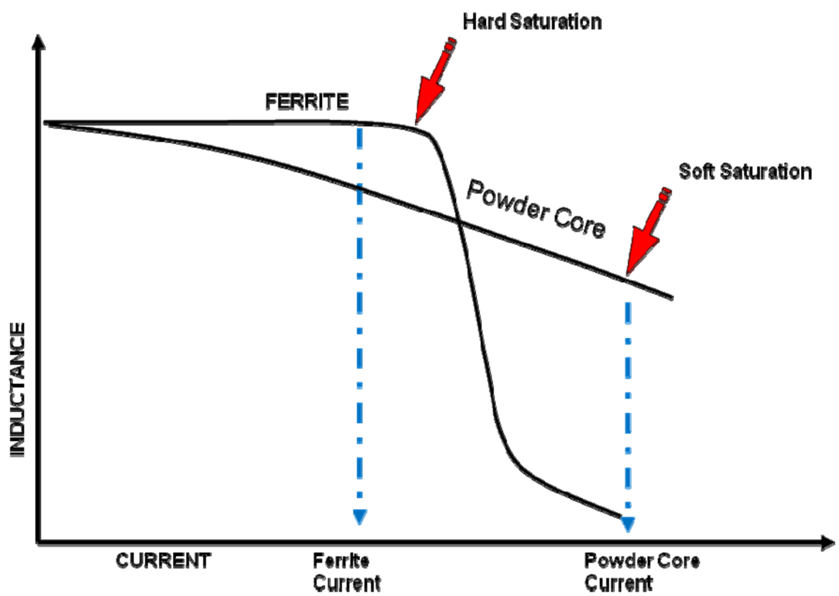

Figure 2 Saturation Graph – Courtesy of Magnetics Inc.

As is shown in Figure 2 hard saturation is a characteristic of ferrite materials which are commonly used in power inductors. Soft saturation is seen in power inductors that utilize powder cores also known as distributed gap materials. Powder cores are more commonly used for custom applications that require soft saturation and the ability to handle higher saturation currents.

With ferrite cores and the hard saturation mentioned earlier, design engineers may need to choose an inductor with a higher Isat rating than what they actually need. In other words, they will de-rate the inductor they choose to avoid the abrupt drop in inductance and the circuit stability issues the abrupt drop in inductance may cause.

For example, if a customer has a need for a 10 uH inductor with an Isat of 1.4 A he can choose the RL9580-1-1.2-100M shown in Table 1, but if it was made with ferrite material the inductance would typically drop abruptly once the 1.4 A is reached. In many cases the customer would simply choose the taller RL9580-1-2.0-100M with an Isat of 2.3 A and de-rate it. If the customer would simply carefully test the first part number mentioned above he may find that this part, with an Isat of 1.4 A, would work well in his circuit. More importantly RL-9580-1-1.2-100M would be shorter than RL-9580-1-2.0-100M.

Renco Part No.	Inductance µH @ 10kHz	Isat (A)	Irms (A)	DCR TYP. @ 25°C (mΩ)	DCR MAX. @ 25°C (mΩ)	Height MAX. (mm)
RL-9580-1-1.2-100M	10.00 ± 20%	1.4	1.3	410	463	1.2
RL-9580-1-2.0-100M	10.00 ± 20%	2.3	1.8	215	243	2.0

Table 1 RL-9580-1 High Current Inductors

Upon further review of Table 1, if the height of the inductor is not critical then RL-9580-1-2.0-100M would be the best choice since the DCR is reduced by almost half and would run cooler than RL-9580-1-1.2-100M The RL-9580 high current inductor family is manufactured with a composite material that has soft saturation characteristics.

Figure 3 RL-9580-1-XX

Signs of Saturation in the Waveform

For those engineers new to power supply design it may not be clear when they are seeing the effects of inductor or transformer saturation in their power supply. A simple oscilloscope measurement of the peak current going through the inductor or primary winding of a flyback transformer (also known as a coupled inductor) will quickly show if the inductor or flyback transformer is saturated.

The top waveform in Figure 4 is a good example of an inductor that is not exhibiting saturation beyond a 15% drop in inductance. The upward slope is clean and straight.

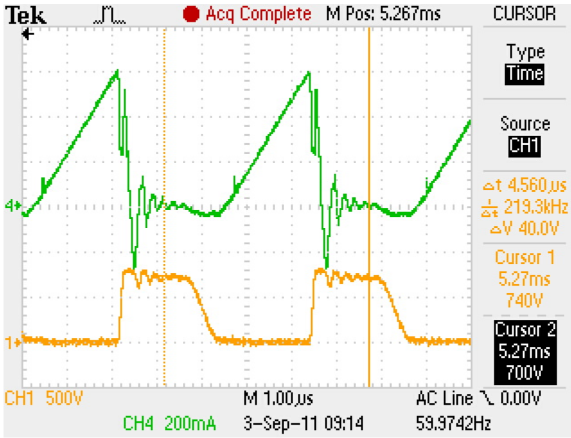

Figure 4 Good Peak Current Waveform

The top waveform in Figure 5 is of an inductor clearly exhibiting saturation beyond a 40% drop in inductance. The slope of the waveform is low and the peak is a very narrow spike.

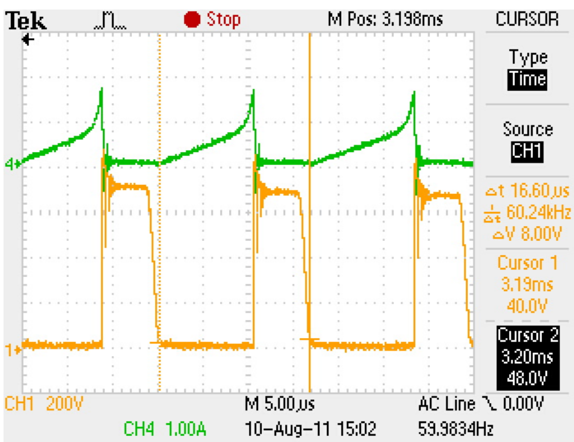

Figure 5 Saturating Waveform

If the waveform of the peak current going through the inductor or flyback transformer resembles Figure 5 then the inductance value of the inductor or flyback transformer in question and the peak current should be re-confirmed. Once the inductance and peak current value is re-confirmed, a standard inductor with a higher Isat current should be selected or the turns of the custom inductor or flyback transformer need to be adjusted to handle a higher peak current.

Further confirmation that an inductor or flyback transformer is saturated occurs when the expected full power is not delivered to the load. In order to confirm that the correct inductance and peak current is specified Equation 1 should be utilized.

$$P = \frac{1}{2} \times L \times Ipeak^2 \times f \qquad \text{Eq. 1}$$

Where:
- P = Power in Watts
- L = Inductance in Henries
- $Ipeak$ = Peak current in Amps
- f = Frequency in Hertz

Inductor Design Basics

Designing a ferrite based inductor that will saturate by less than 10% is a fairly straightforward process. Once size constraints are determined an inductor core can be chosen and then Equation 2 can be used to calculate the number of turns necessary to support the required inductance and peak current with a 10% or less drop in inductance. The key is to use a peak flux density of 3,000 Gauss or less to keep the core losses to a minimum and to keep the drop in inductance to less than 10%.

$$N = \frac{L \times Ipeak \times 10^8}{Bpeak \times Ae} \qquad \text{Eq. 2}$$

Where:
- N = Number of Turns
- L = Inductance in Henries
- $Ipeak$ = Peak current in Amps
- $Bpeak$ = Peak flux density in Gauss
- Ae = Core area of selected core in cm^2

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Designing a powder core based inductor is slightly different, but the inductance and peak current are utilized in the design formulas. An in depth analysis of designing with powder cores can be found at www.maginc.com & www.micrometals.com.

Conclusion

This paper has defined peak current as it is related to an inductor. In addition, hard saturation has been compared to soft saturation and the different materials that exhibit hard and soft saturation were discussed. Furthermore, waveforms of a good waveform and saturating waveform were reviewed. Finally, the basic formula based on Faraday's Law used in the design of ferrite inductors was introduced.

If you need assistance to select the appropriate inductor for your application or to design your custom inductor or transformer contact Renco Electronics' Design Engineering team at Engineering@rencousa.com or call the Engineering hotline: 1-800-645-5828

References

[1] For further discussion on frequency and magnetic components refer to the application note - APN-100 titled, *The Effects of Increasing Frequency on Magnetic Components*. Available at www.rencousa.com

[2] For further discussion on core loss refer to the application note - APN-100 titled, *The Effects of Increasing Frequency on Magnetic Components*. Available at www.rencousa.com