

Selecting inductors for power applications

Choosing the right power inductor is a function of tradeoffs

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Like many components in the industry, power inductors are being impacted by the trend toward smaller electronic devices with enhanced functionality—requiring increased density of components on the board. The miniaturization of battery-powered devices also requires more compact circuit-board designs, and therefore smaller but more-effective inductor designs.

Tradeoffs

Selecting a power inductor is a function of tradeoffs. Most designers are looking for the lowest possible price, the lowest possible resistance, the highest possible current rating, and the best saturation characteristics possible for the space available on the circuit board.

Manufacturers offer a wide range of inductance values in both horizontal and vertical package sizes, and offer them in surface-mount as well as through-hole configurations. The key to achieving the desired electrical performance is to select the appropriate core material and design respective of the tradeoffs.

Options

One way to define the proper inductor component selection is to list the options for core material



Inductors come with a wide range of inductance values in both horizontal and vertical package sizes, and in surface-mount as well as through-hole configurations.

and design and outline the advantages and disadvantages of each. The options might include toroidal and/or gapped ferrite packages. There is also a wide variety of molded and/or open-construction inductors to choose from that are totally ungapped and typically either a straight or bobbin coil form.

Each available core material will be combined with various wire sizes and turns to determine the actual inductance value of each inductor. However, the various core styles determine how well the part ultimately performs in different areas, such as shielding, saturation, and dc resistance.

High-flux toroids

High-flux inductors are shielded,

offer excellent saturation characteristics and low core loss, and are highly temperature stable. They come in a variety of sizes and permeability, and are the most popular choice for filter inductors up to 1 MHz. On the downside, they are limited in inductance value; typical sizes can only support inductance up to about 1,000 μ H.

Kool Mu toroids

Typically at a lower cost than high-flux toroids, Kool Mu toroids are also shielded, offer a low core loss, and come in numerous sizes and permeability. The disadvantage is again a limited inductance value, where typical sizes can only support inductance up to about 1,000 μ H. Relative to the high-flux toroid, temperature stability is not as desirable and saturation occurs at much lower current levels.

Powdered-iron toroids

Priced the lowest of all the types listed, powdered-iron toroids provide a temperature stability that is fair to good at high frequencies. However, they too are limited in inductance value, and inductance varies substantially with changes in ac excitation voltages. Performance can degrade after 1,000 hours of life when exposed to temperatures of 125°C, although some work is being done to improve this degradation.

Ferrite toroids

Providing a high permeability for

Calculating inductor current rating

All the calculations for figuring the current rating of an inductor are based on the basic power equation $P = I^2 R$. As part of the equation, the resistance created—due to the temperature rise as the current heats the part—must also be considered.

$$P = I^2 R [1 + (0.00385) (T_{\max} - 25)] \quad (1)$$

Once we have the total power calculation, we can now calculate the power per degree C, called the thermal conductance factor or G_t . This factor describes how well the component will dissipate heat as the current causes the part's temperature to rise. Thermal conductance factor is calculated using the equation:

$$G_t = \frac{P}{(\text{Temperature rise})} \quad (2)$$

With the thermal conductance factor, the designer can estimate the current rating for any ambient temperature by changing the first equation to solve for this current rating:

$$I = \sqrt{P/R_{dc} [1 + (0.00385) (T_{\max} - 25)]} \quad (3)$$

Modifying equation 2 to solve for P,

$$P = G_t (\text{Temperature rise}) \quad (4)$$

and substituting the results from equation 4 into equation 3 for power:

$$I = \sqrt{G_t (\text{Temperature rise})/R_{dc} [1 + (0.00385) (T_{\max} - 25)]} \quad (5)$$

Any temperature rise can be entered into equation 5 to determine the new current rating for a given ambient temperature point. The same equation can be used to recalculate the current rating if a DCR change is made. If, for example, the manufacturer changes to a heavier wire size to decrease the DCR, this equation can be used to calculate the new current rating.

It should be noted that this technique can be used to determine G_t for a particular series of parts, and that information can then be applied to calculate new ratings. This approach is safe as long as nothing else changes in the design relative to materials and size.

The largest determining factor in the actual G_t is the surface area of the part. However, thermal conductivity of the materials also plays a part in the component's ability to dissipate heat. Therefore, any changes in core material, molding, potting materials, or wire type (different than copper) can have an effect on the G_t factor.

KEY: P = Power of the inductor
R = Dc resistance
I = Current rating
 T_{\max} = Max continuous operating temp.

common-mode applications, shielded ferrite toroids suffer in differential modes, where they have a tendency to be rapidly saturated by dc. Gapped toroids and other gapped configurations are available to handle the dc if necessary.

Gapped ferrites

Gapped ferrites include Pot cores, E cores, EI cores, and others. These inductors can achieve very high inductance values and will pass some dc without saturating.

Their versatility is due to the many different materials that are available to meet a desired frequency and/or impedance. However, cost is usually high due to assembly costs and gapping of the cores.

Ferrite bobbins

The open air-gap of ferrite bobbins creates excellent saturation characteristics and enables achievement of very high inductance values. They also have excellent winding form because of the bobbin

shape. The disadvantage is that they are not shielded, and adding a shield closes the air gap and eliminates the saturation advantage.

Other open-gap shapes

These open-gap inductors also offer excellent saturation characteristics. They are offered in a wide variety of axial-leaded, radial-leaded, and surface-mount styles.

Material selections usually include ferrite, powdered iron, phenolic, and ceramic. Sizes can range from 0.10 x 0.08 in. to over 1 in. long.

Adding to their versatility, most shapes come in molded versions to seal against moisture and add protection during processing. Although most disadvantages can be avoided via material/design selection, most of these inductors are not shielded since shielding would close the gap and reduce the saturation current level.

Current rating

An inductor's current rating is

based on its ability to withstand dc current, and thus the rating is essentially the thermal capability of the component. Usually specified in amperes dc (Adc) or milliamperes dc (mA dc), dc current rating is the maximum current that should be allowed to flow through the component based on a specified ambient and maximum operating temperature.

If the specified current rating is exceeded and the ambient temperature is realistic, the component will exceed its maximum operating temperature, and may overheat and potentially fail. The notes on most specification sheets identify both the ambient temperature and temperature rise, or the ambient temperature and maximum operating temperature.

If the temperature rise is not specified, it can be calculated by simply subtracting the ambient temperature from the maximum operating temperature (see *box*, "Calculating inductor current rating").