Whitepaper

The Advantage of Using Metal Over Ferrite in Power Inductors

Power inductors are a basic component used in many signal and power conditioning applications to attenuate, block, filter, or store energy. The increasing high powers and switching frequencies used in today's power circuits are imposing market challenges to component manufacturers in both the materials and packaging levels, pushing pow-er inductors to a much higher rated current while fitting in ever-shrinking form factors.

This article discusses how improvements in metal-based power inductors meet today's changing market require-ments of power inductors.

TAIYO YUDEN

Power inductors are a basic component used in many signal and power conditioning applications to attenuate, block, filter, or store energy. The increasingly high powers and switching frequencies used in today's power circuits push power inductors to a much higher rated current while fitting in ever-shrinking form factors. This is a challenge at both the materials and packaging levels, where component designers must diverge from the traditional ferrite core material while also innovating the inductor construction in order to miniaturize these devices without degrading other parameters such as inductance and DCR. This article discusses the differences between traditional ferrite and metal-based power inductors and how the many improvements found in metal-based power inductors meet the changing market requirements of power inductors.

What Are Power Inductors Used For?

Inductors are generally selected based upon the inductance value, current rating, DC resistance (DCR), operating temperature range and whether or not they are shielded or unshielded. All of these parameters should be optimized based on the application circuit it is used in. This can range from filtering EMI in the AC inputs of a power supply to being used as a DC filter choke, reducing both ripple voltage and current at the output of a switching power supply. The self-induction property of inductors also allows these devices to store power in DC-DC converters—once the switching element turns off, the inductor will discharge its stored current. Any type of voltage regulation circuit (e.g., DC-DC converters, power supplies, etc.) will almost always leverage a power inductor.

Choosing the Right Inductor

The inductance value will ultimately impact the ripple current of a DC-DC converter. A large inductance value will decrease the ripple current of the converter; however, this will also impact the cost and size of the application. As implied by its name, the DCR of the inductor is the resistance of the inductor when DC current passes through it. Having a lower DCR will reduce loss and improve the power circuit's efficiency. The the saturation current (Isat) is the maximum current allowed before the inductor will enter magnetic saturation and observe a drop in inductance. In high current applications, it is important to have a power inductor with a high Isat; however, this can also lead to a much larger component.

The Need for Small Form Factor, High Current Power Inductors

The need for a high current handling power inductor is increasingly important as semiconductor power supplies have transitioned from higher 3.3 volt rails and lower currents to requiring a high currents and lower voltages (i.e., 1.0 V and 1.2 V rails) as chip design technology advances (Figure 1). Additionally, the development of smaller-sized electronic components and the progression of mounting technologies to enable a slimness and thinness of the enclosure increases demands for miniaturization of all the internal electronic components including the power inductor.

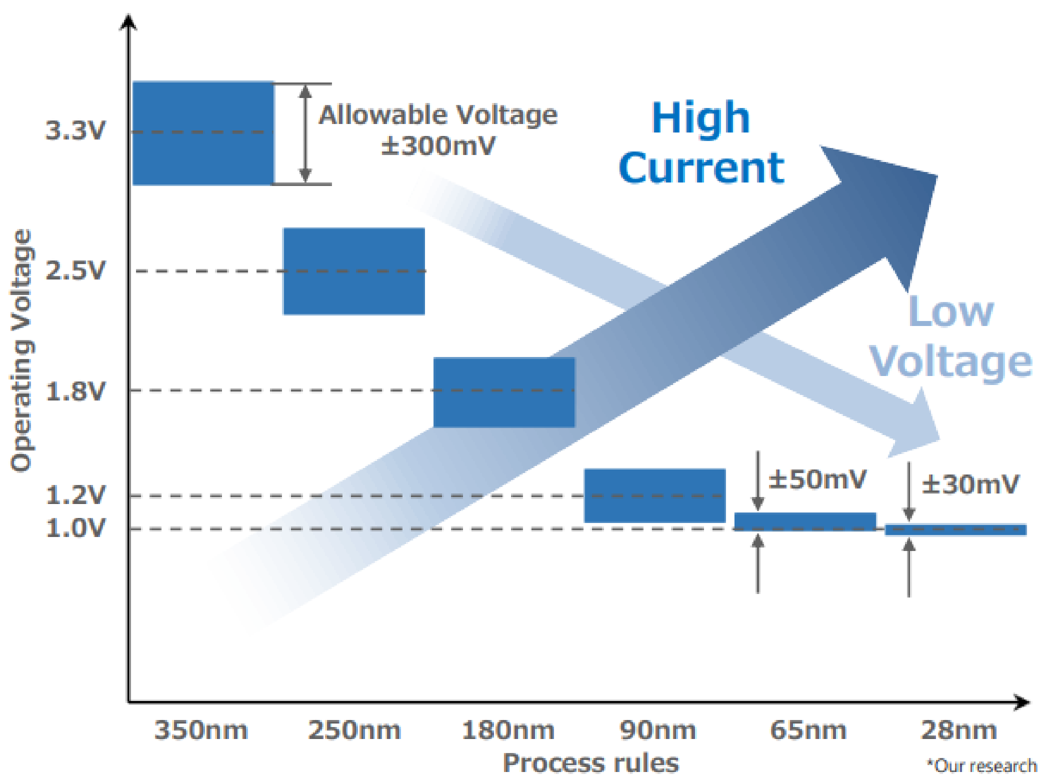

Figure 1: The transition of semiconductor power supply voltages. (Source: TAIYO YUDEN)

However, there is generally a tradeoff between high current capability and size for power inductors. Typically, land patterns need to be changed for bigger case sizes to withstand higher currents. Moreover, a small size generally translates into insufficiency inductance or saturation current. The unique metal alloy of the L□EU wire-wound power inductors and the combination of materials and the patented construction of the L□CN multilayer power inductor allows designers to have both a high saturation current and inductance in a small case size (Figure 2).

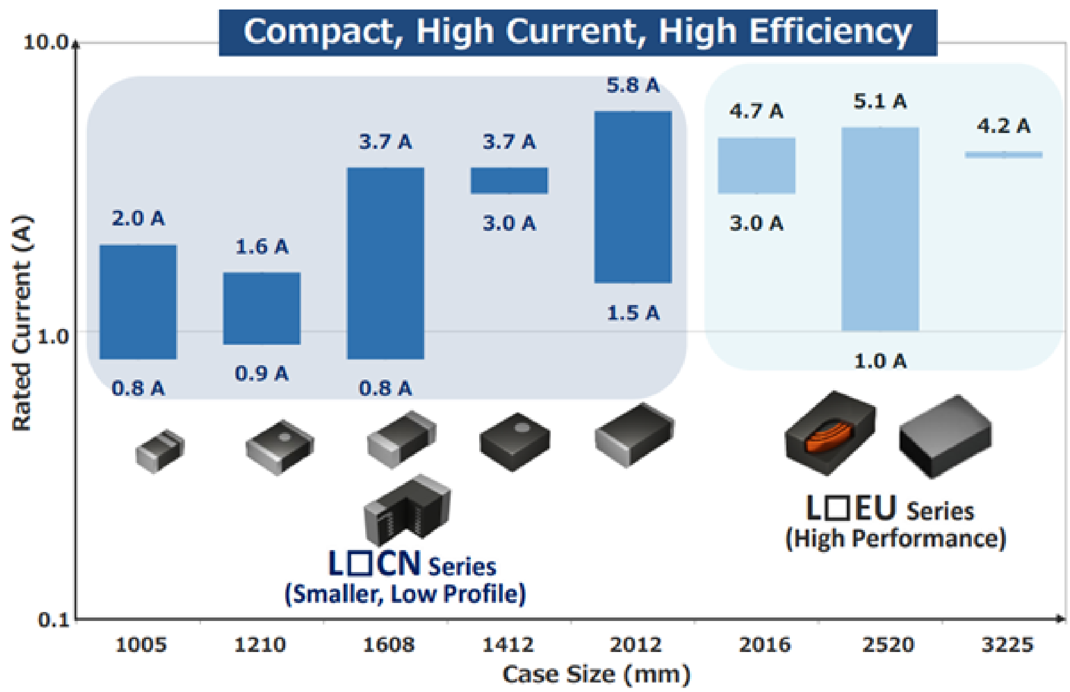

Figure 2.: Current rating versus case size of the L□CN and L□EU series.. (Source: TAIYO YUDEN)

The Various Constructions of Power Inductor

In order to understand the benefits of each of these components, it is important to note the conventional layout of both the wire-wound and multilayer power inductors (Figure 3). The multilayer inductor is created by printing a pattern on a ceramic sheet containing ferrite. The sheets are then laminated and fired. The final piece is finally assembled, pressure-bonded, and fired, and external electrodes are formed at the ends. Generally, a high inductance is formed by using a material with a high magnetic permeability.

The wire-wound inductors have a coil formed inside (or on the surface of) a magnetic material such as a ferrite. The coil is wrapped around the inner core with a predetermined number of turns and an outer core that encapsulates the inner core. The higher the number of turns, the more inductance; the lower the number of turns, the lower the DC resistance (DCR). The coil is coated with an insulation resin to increase its operating temperature. External electrodes are attached to both the ends of the coil with silver pastes or electroconductive metal pieces and are applied to the lower end portion of the inductor.

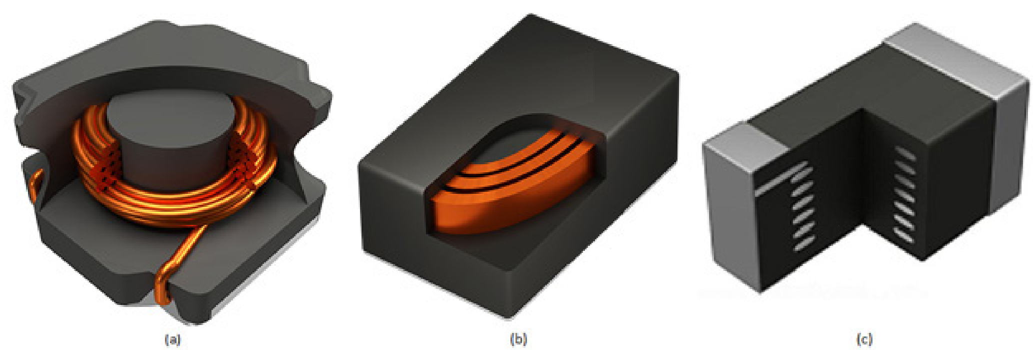

Figure 3: Cross-sectional view of a ferrite-based wire-wound inductor (a), a metal-based wirewound inductor (b), and a metal multilayer inductor (c). (Source: TAIYO YUDEN)

The inner cores are generally compacted powder magnetic cores or ferrite cores. Creating these cores is a complex process that could involve compression molding and/or sintering and heat treatment to bind the magnetic alloy grain and break down any binders that allow for the mixture of elements. Recent processes often prefer metal magnetic alloy over the traditional ferrites as they provide an advantage over their ferrite counterparts.

Improvements to the Wire-Wound Inductor

TAIYO YUDEN offers enhancements in both the wire-wound and multilayer-type power inductors through the use of metal materials. For wire-wound power inductors, this yields a much smaller case size than ferrite-based wire-wound counterparts with the same inductance and current ratings. An example can be seen in Table 1 below where the ferrite-based L□XN and metal-based L□DP series with the same 4mm square case size are compared. The vast improve-ments contributed to the innovations in materials used within these inductors.

Figure 4: The performance can be drastically improved by using metal materials in wire-wound inductors. (Source: TAIYO YUDEN)

TAIYO YUDEN applies iron-based amorphous alloys coated with thermally stable oxides for the core material in order to achieve this high performance in a miniaturized structure. There is a mixed system consisting of iron (Fe), silicon (Si), and a metal element that is easier to oxidize than iron—this typically includes chromium (Cr), titanium (Ti), or aluminum (Al). The higher the silicon content, the better the insulation resistance and magnetic permeability of the core. The lower the silicon content, the more moldable the core is.

Metals such as Cr form a passive state during heat treatment to prevent excessive oxidation and develop strength and insulation resistance; however, too much can impact the core's magnetic properties and thus the properties of the power inductor. There is a delicate balance struck between these materials when forming a power inductor core and this can only be analyzed with a scanning electron microscope (SEM) to ascertain the core's chemical composition.

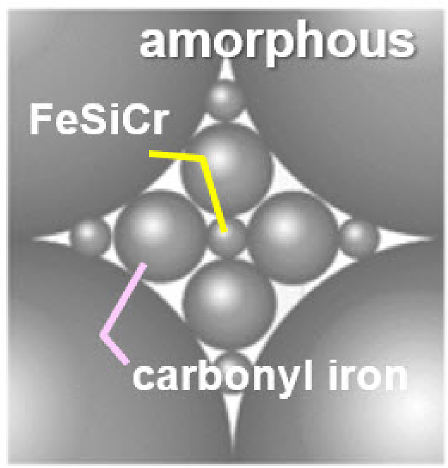

Figure 5: Mixed system new design of three particle sizes used in TAIYO YUDEN's wire-wound power inductors. (Source: TAIYO YUDEN)

The introduction of a metal into the alloy used for the power inductor increases the rated current and reduces the DCR of the inductor while also reducing the footprint of the inductor package. The metal magnetic alloy can achieve higher saturation magnetic flux densities (Bsat) than ferrite; this, in turn, allows for a higher current operation. The lower DCR allows for a more efficient power supply design.

These improvements can be seen in the miniaturized metal wire-wound □EU series to enable a high current and a low DCR in a small footprint, such as less than 1mm case size. The L□DN/L□DP series of metal wire-wound inductors feature a high current, low profile and improved DC bias characteristics while allowing designers to be able to use the footprint of the previous ferrite-based L□XN series. TAIYO YUDEN's offering of both wire-wound and multilayer power inductors can be seen in Figure 6, where the relative case sizes and current ratings are made apparent.

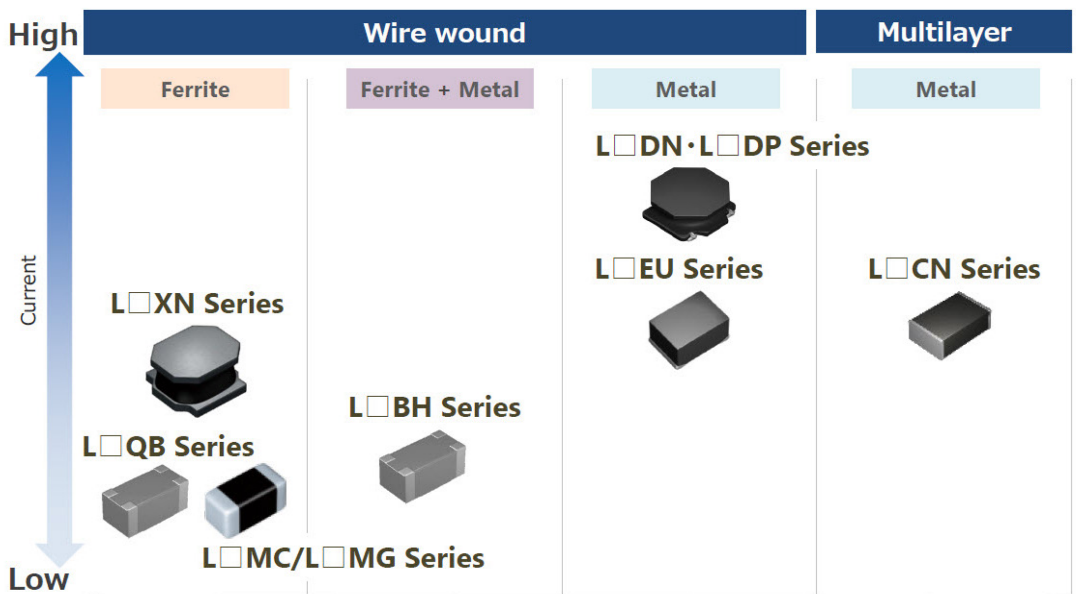

Figure 6: *TAIYO YUDEN's large portfolio of power inductors with mixed case sizes and current ratings depending on the customer's needs. (Source: TAIYO YUDEN)*

Improvements to the Multilayer Inductor

The L□CN series of multilayer inductors realized high-performance and ultra-miniaturization by combining magnetic materials and a multilayer structure. The heat-treated iron powder within the L□CN ensures insulation with a thin crystalline oxide film (Figure 7). The multilayer structure makes best use of the material properties of iron while also utilizing the large current, high efficiency, and high heat resistance of the metal materials.

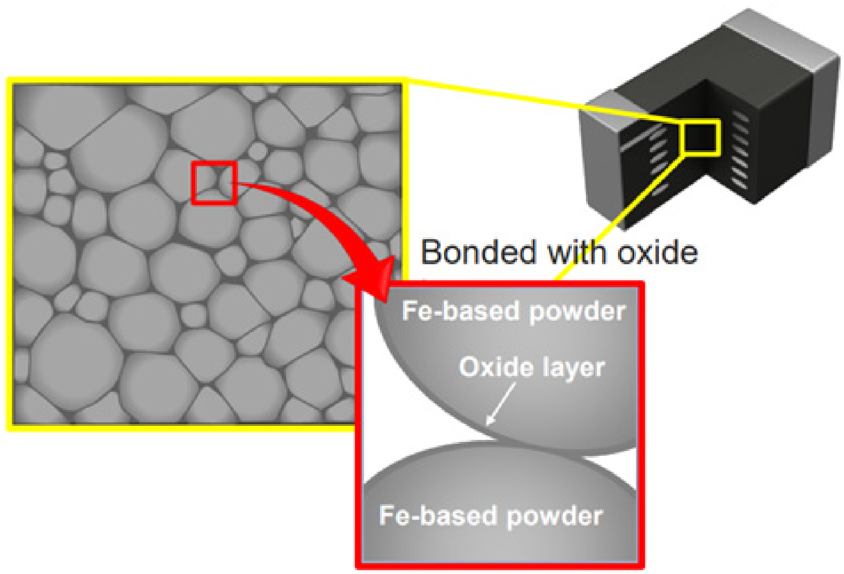

Figure 7: TAIYO YUDEN' L□CN leverages a unique iron-based powder that is optimal for the multilayer method. (Source: TAIYO YUDEN)

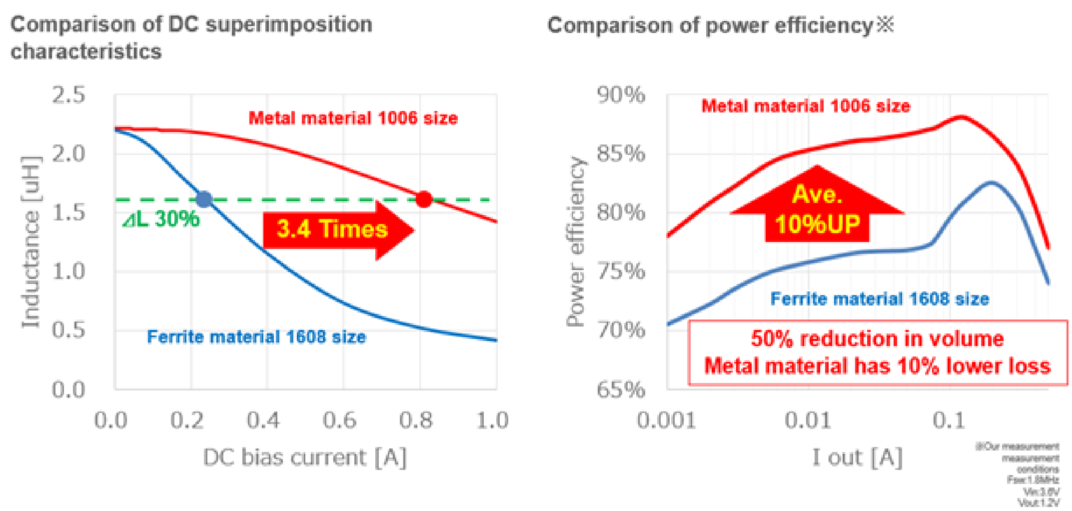

Figure 8: *Metal versus Ferrite performance comparison in multilayer power inductor.*
(Source: TAIYO YUDEN)

TAIYO YUDEN's Small but Mighty Power Inductor

The unique combination of the magnetic alloy and unique construction of TAIYO YUDEN's power inductors improve on the current and the DCR of the component while drastically reducing the volume of the inductor. These improvements directly impact power circuits implementing them, removing the current and size tradeoff that designers typically face when employing power inductors. TAIYO YUDEN has an ongoing legacy in the materials research and development and fabrication of inductors, allowing the company to steadily improve on past generations of products to produce a portfolio of cutting-edge inductors that serve modern power electronics' needs. TAIYO YUDEN is able to provide cutting edge power inductors that meet the size, profile, and power constraints of modern power delivery networks.

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