The Fundamentals of Power Inductors

Coilcraft®

The Fundamentals of Power Inductors

CONTENTS

TECHNICAL ARTICLE

Looking Beyond the Static Data Sheet

Exploring the Need for Smarter Power Inductor Specification Tools

"Understanding the Data Sheet" is a favorite topic of many technical writers, including this one. Considering the fast pace at which technology advances, these articles can be very helpful for both newer engineers and savvy veterans as they attempt to obtain performance data that can be critical to their design. However, it is important to realize that data sheets are inherently limited. Many key parameters are application dependent, varying with characteristics such as frequency or temperature and making it difficult to capture a component's performance in a single spec or curve. No matter how clearly the data is portrayed or how cleverly the data sheet is written, manufacturers simply cannot perfectly anticipate how a customer intends to use their products.

Electronic selection and analysis tools help close this informational gap by providing "smarter" technical data, allowing the customer to evaluate the data she wants instead of looking at the picture the manufacturer chose to provide.

Data Sheet Dangers: An Illustration

A key component of DC-DC converters, the power inductor has a significant impact on efficiency, transient response, overcurrent protection and physical size. Only with a clear picture of the pertinent inductor parameters can a user make an informed selection of the best inductor for her application.

Take, for example, the inductor characteristic of saturation current (Isat), typically defined on inductor data sheets as the amount of dc bias current that causes a specific amount of inductance decrease. This is usually the current that causes 10%, 20% or 30% inductance drop. Let's examine a nominal 100 µH inductor (Coilcraft part number LPS3015-104) with 30% inductance drop Isat rating of 0.26 Amps.

This rating provides a convenient number with which to compare this part with other inductors, but that's all it really does. Defining saturation as an inductance drop of 30% is arbitrary and not necessarily meaningful to any particular application. One could just as easily define saturation as 10% or 50% inductance drop.

In fact, inductor manufacturers have used all these definitions at one time or another, generally making fair and direct comparisons between products difficult.

A better picture of inductor performance vs dc bias is provided by looking at the L vs I curve for the LPS3015-104 (Figure 1) instead of a single Isat number. However, the practical task of comparing parts based on the curves can still be trickier than one might expect.

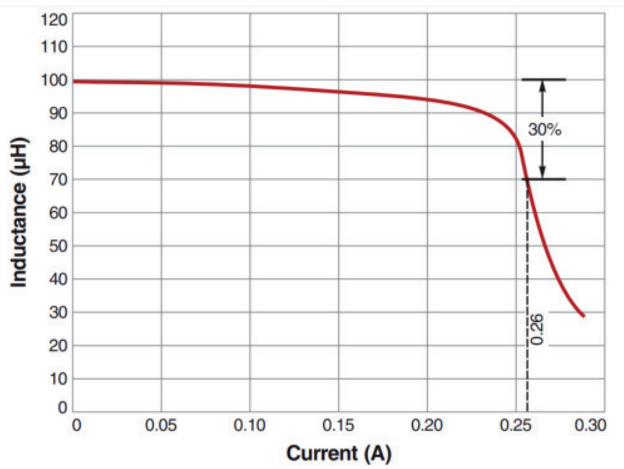


Figure 1. Typical saturation current rating

Taking a quick glance at the two curves in Figure 2, one might jump to the conclusion that these two 100 µH inductors have similar Isat ratings. The curves look similar. However, closer inspection is needed to notice the different horizontal scales. In fact, the Isat for the LPS6235-104 is approximately two times that of the LPS3015-104 – not even close!

Careful reading of the curves by engineers would always lead to this correct understanding, but why make it difficult? The chance for human error would be reduced if the compared parts were shown on the same graph.

Electronic Selection and Analysis Tools

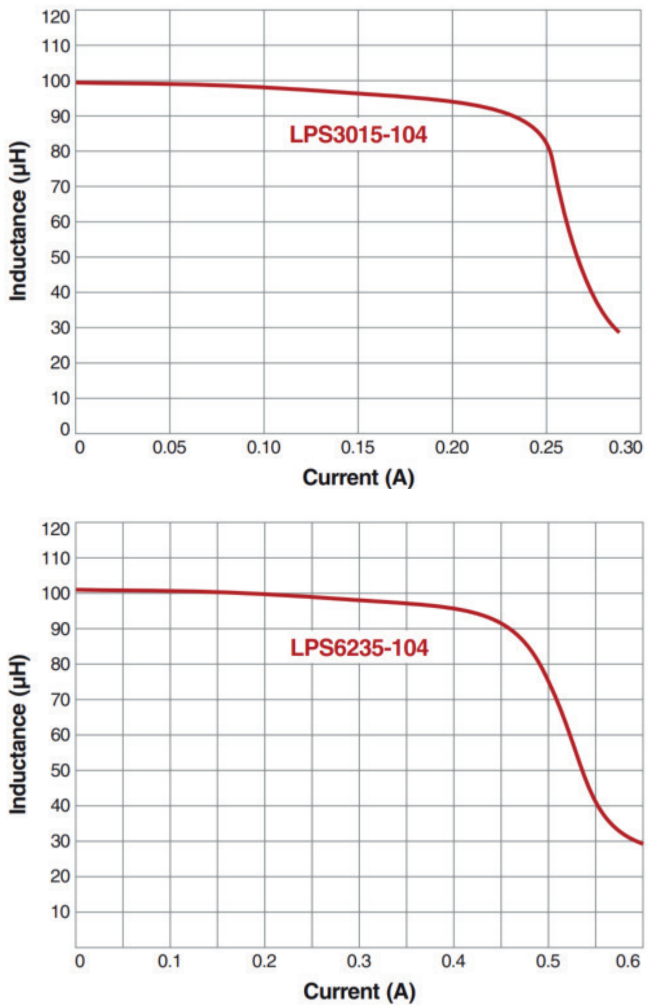


Figure 2. Saturation current ratings for Coilcraft's LPS3015-103 and LPS 6235-103 power inductors

Some online selection and analysis tools now provide this function, providing all the essential product specifications needed for a proper comparison. For example, Coilcraft's *Power Inductor Finder and Analyzer (Compare Tab)* design tool allows a user to select the same two inductors previously discussed and have their L vs I curves plotted side-by-side on the same graph, clearly revealing the LPS6235-104's superior performance (Figure 3).

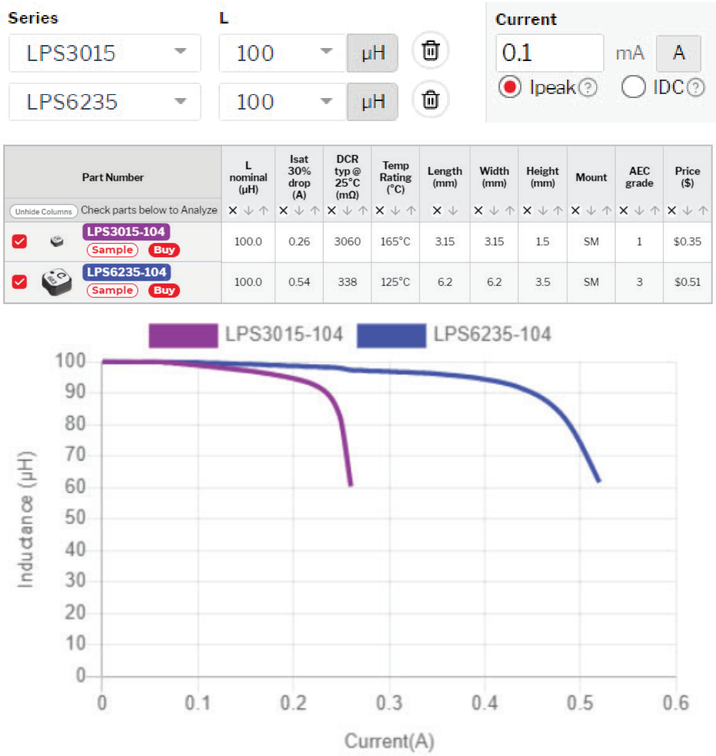


Figure 3. Side-by-side comparison of L vs. I curves

In addition to the L vs I curves, the summary provides other pertinent inductor specifications, including DCR, maximum temperature, size, and relative price. Unlike static data sheets, the information is all here in one place, allowing the user to make direct comparisons without having to sift through non-comparable data sheets.

Well-designed tools can also provide deeper, more meaningful product comparisons. For example, with most power designs, it is not very meaningful to know the inductance at zero current. After all, inductors don't really function without current. What is important is being able to find an inductor that can provide a specific L and I combination.

Inductance at Current

Most inductor manufacturers do offer basic online parametric search tools that allow an engineer to generate a list of products by selecting performance attributes like inductance and current. Some of these tools allow the user to sort the list (by height, for example) to help her identify the best parts for her application. Unfortunately, too many manufacturers' design tools stop here, leaving it to the engineer to link to specific product data sheets in order to conduct her own analysis. The *Power Inductor Finder and Analyzer (L@I Tab)* tool (Figure 4) goes further, not only generating a sortable list of products and plotting the L vs. I curves of up to four parts along the same axis for easy comparison, but then also providing important temperature derating analysis.

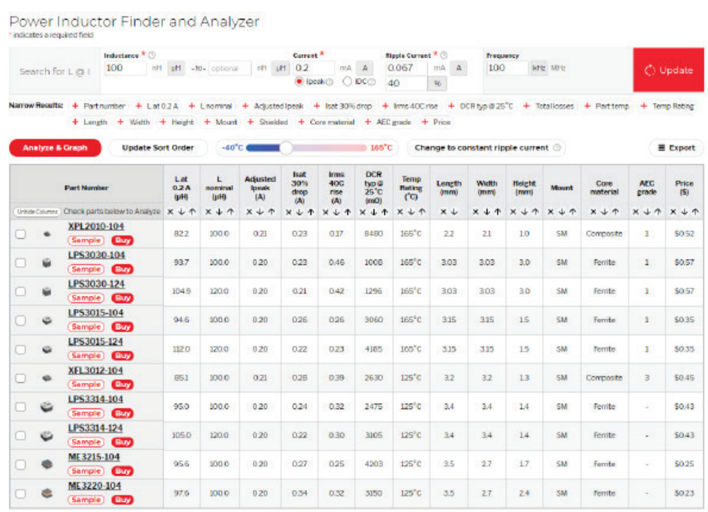
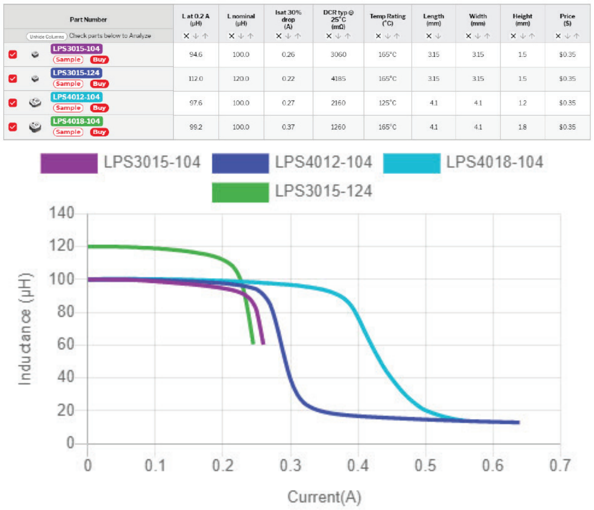


Figure 4. Coilcraft's Power Inductor Finder and Analizer Tool (L@I Tab)

The L @ I search can be performed at any temperature from −40°C to +125°C, with curves shown for the temperature selected and the DCR derated accordingly (Figures 5 and 6, on following page).



Part Number	L at 0.2 A (µH)	L nominal (µH)	Isat 30% drop (A)	DCR typ @ 25°C (mΩ)	Temp Rating (°C)	Length (mm)	Width (mm)	Height (mm)	Price ($)
LPS3015-104	94.6	100.0	0.26	3060	165°C	3.15	3.15	1.5	$0.35
LPS3015-124	112.0	120.0	0.22	4185	165°C	3.15	3.15	1.5	$0.35
LPS4012-104	97.6	100.0	0.27	2160	125°C	4.1	4.1	1.2	$0.35
LPS4018-104	99.2	100.0	0.37	1260	165°C	4.1	4.1	1.8	$0.35

Figure 5. L vs. I curves at 25°C

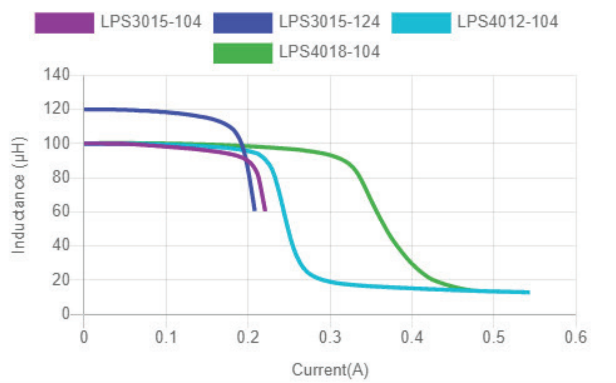


Figure 6. L vs. I curves derated for 85°C

This is powerful information for any engineer looking to optimize her design. Consider a case in which the design calls for an inductance value of 100 µH up to 0.2 Amps. Reviewing only the parametric search results, the designer might identify Coilcraft LPS3015-104 as a candidate, but we can see in Figure 7 that this inductor falls below the target of 100 µH at 0.2 Amps.

A logical next step for most designers would be to select a larger part such as the LPS5030-104. The part meets the performance target, but measuring 5.0 mm square compared to the LPS3015-104, which measures 3.2 mm square, this choice would result in a 244% larger footprint.

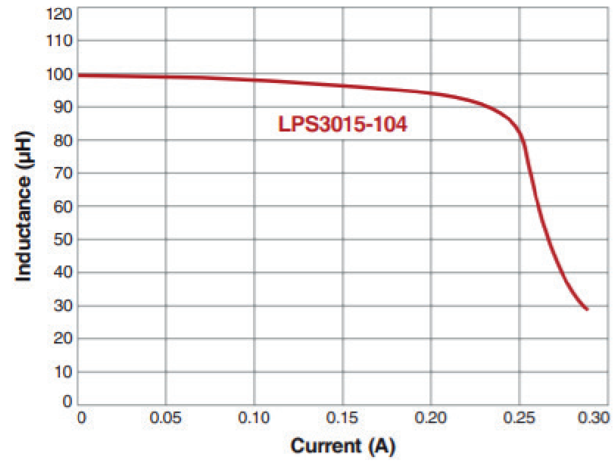
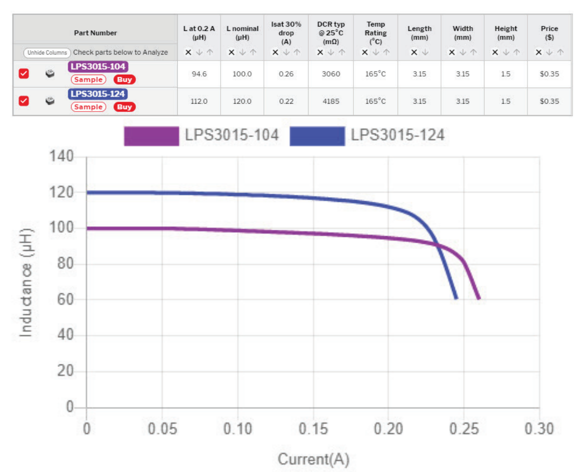


Figure 7. L vs. I graph for Coilcraft LPS3015-104 power inductor

The *Coilcraft Power Inductor Finder and Analyzer (L@I Tab)* search engine provides a more powerful way of solving the problem. Whereas searching the data sheets for nominal 100 µH inductors will find parts that measure 100 µH, the search engine finds parts with the right combination of L @ I for the application. In the present example, the tool identifies another part of the same size that meets the target at 25°C, namely LPS3015-124. This part meets the application need in the smaller footprint (Figure 8). An engineer carefully browsing through data sheets might find this solution, but it would be much less likely. The search engine provides a richer variety of optimized solutions using dynamic data.



Part Number	L at 0.2 A (µH)	L nominal (µH)	Isat 30% drop (A)	DCR typ @ 25°C (mΩ)	Temp Rating (°C)	Length (mm)	Width (mm)	Height (mm)	Price ($)
LPS3015-104	94.6	100.0	0.26	3060	165°C	3.15	3.15	1.5	$0.35
LPS3015-124	112.0	120.0	0.22	4185	165°C	3.15	3.15	1.5	$0.35

Figure 8. L vs. I graph comparing Coilcraft LPS3015-104 and LPS3015-124 power inductors

Important Example

An important trend is the growing use of a new type of power inductor with the core molded around a winding instead of the more traditional winding on a solid core. One characteristic of this technology is a soft saturation curve. Due to the distributed air gap in the molded core, the B-H loop is flattened and the inductor saturates more gradually (Figure 9).

Part Number	L at 10 A (µH)	L nominal (µH)	Isat 30% drop (A)	DCR typ @ 25°C (mΩ)	Temp Rating (°C)	Length (mm)	Width (mm)	Height (mm)
Unhide Columns Check parts below to Analyze								
XGL6060-472 Sample Buy	3.3	4.7	10.2	9.1	165°C	6.91	6.71	6.1

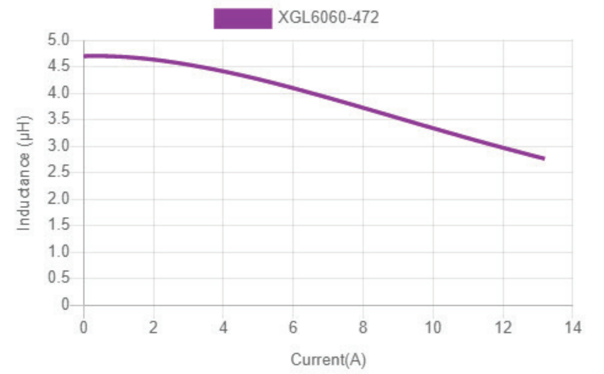


Figure 9. "Soft" saturation curve of Coilcraft XGL6060-472 molded power inductor

A saturation curve like that in Figure 9 is a good demonstration of the artificial nature of defining saturation by means of inductance drop. The method works well when the curve has a well defined knee, but comparisons between soft saturating inductors using the traditional Isat rating can be greatly misleading, as differences between similar parts are exaggerated (Figures 10 and 11).

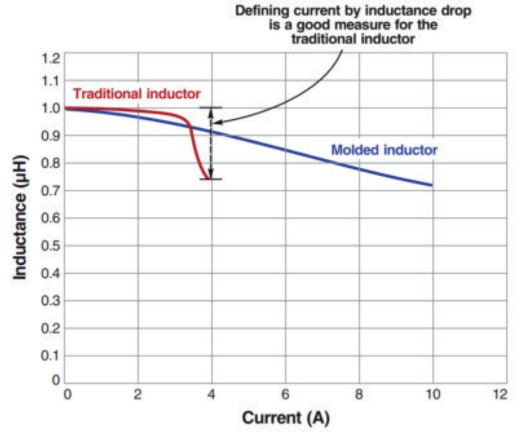


Figure 10: Saturation curve comparison between traditional and molded inductors.

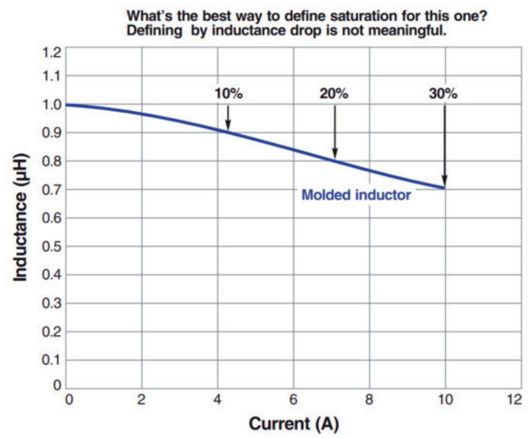


Figure 11: Comparing soft-saturating inductors using traditional inductance drop can be misleading

Consider the example of comparing the two inductors listed in Figure 12 (see pg. 8). The DCR of Inductor 2 is 23% better than Inductor 1, and it occupies less than half the board space, but the Isat ratings suggest that Inductor 2 has significantly less L vs. I and won't handle nearly as much peak current. But the Isat ratings have exaggerated the difference between inductors and the parts are more similar than these ratings suggest.

	Isat (30%)	DCR typ	PCB footprint
Inductor 1 – XAL6030-332	12.2 A	26 mOhm	36 mm
Inductor 2 – XAL4030-332	5.5 A	20 mOhm	16 mm

Figure 12. This table suggests that there is a great disparity between these inductors

Taking a closer look at the L vs. I curves for these two products (Figure 13), we can see that while the curves are certainly not identical, they are not nearly as different as one would expect from the Isat ratings. Whereas the Isat ratings might imply that inductor 1 has more than 2 × current rating, the true measure of the difference is closer to only 25%.

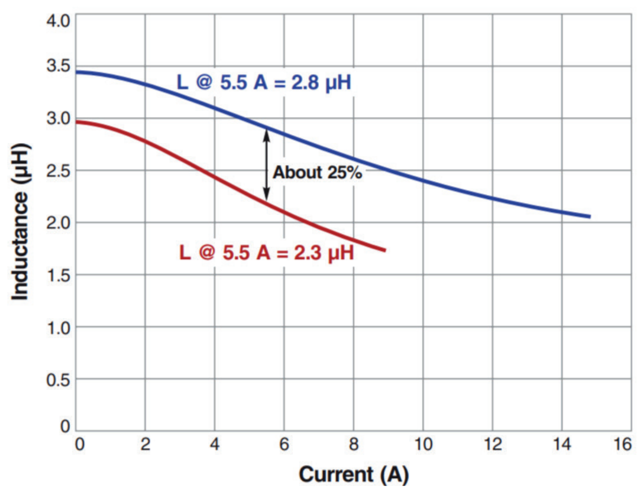


Figure 13. Saturation curves reveals the two inductors are closer than the lsat ratings would indicate

Isat ratings define the inductor using the zero current inductance as the baseline. A more useful concept is *Inductance at Current* as calculated by the Coilcraft *Power Inductor Finder and Analyzer (L@I Tab)* tool. Comparing these two inductors at 5.5 A shows the meaningful difference is 2.9 µH vs. 2.3 µH. This 25% difference is not nearly the difference suggested by the Isat ratings of 12.2 A and 5.5 A. While that extra inductance might or might not be important for any particular design, it is important for the designer to have access to all the right information to make the best choice rather than being limited by traditional data sheet ratings.

Conclusion

Web based selection and analysis tools are powerful additions to the engineer's toolbox, presenting a more complete picture of product performance, and allowing the engineer to optimize the design.

TECHNICAL ARTICLE

Selecting the Best Inductor for Your DC-DC Converter

Abstract

Proper inductor selection requires a good understanding of inductor performance and of how desired in-circuit performance relates to the information available in supplier data sheets. This article walks both the experienced power conversion specialist and nonspecialist through the inductor catalog and the important specifications.

Introduction

The use of DC-DC converters is increasing. As electronic systems become more miniaturized, mobile, complicated, and popular, the power requirements become more varied. Available battery voltages, required operating voltages, size, and shape requirements are ever changing, leaving equipment designers constantly in need of new power conversion solutions. As product requirements constantly drive performance improvement and size reduction, optimization is crucial. A "one size fits all" approach to power conversion does not fit all applications. For example, low profile components as shown in Figure 1 are much in demand.

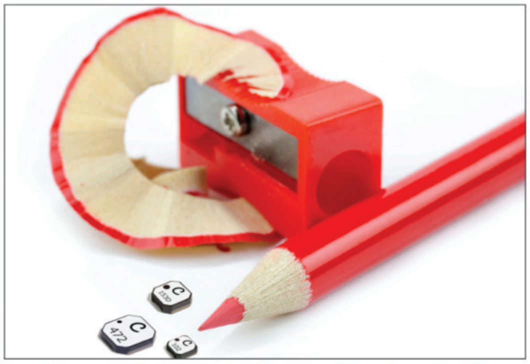


Figure 1. Thin Inductor Shapes Allow Low Profile Converter Design

Not only is the market for purchased converters growing, but also many circuit designers now design their own DC-DC conversion circuits instead of relying on power supply specialist companies. This increases the number of circuit designers involved in selecting components. Basic DC-DC conversion circuitry is fairly mature technology and continues to evolve rather slowly. Because of this it has become quite practical and useful for authors to create "cookbook" design aids by which equipment designers can create their own converter design. Software is also readily available to facilitate these designs[1].

After deciding on a circuit topology, one of the key design tasks is component selection. Many circuit design programs produce a list of the required component values. The task for the designer then is to get from knowing the desired inductance value to selecting an available component to do the job. Inductors that can be used in DC-DC converters come in a wide variety of shapes and sizes.

Figures 2 and 3 show just two of the possible inductor shapes. In order to compare types and choose the optimal part for the application, a designer must rely on correctly understanding published specifications.

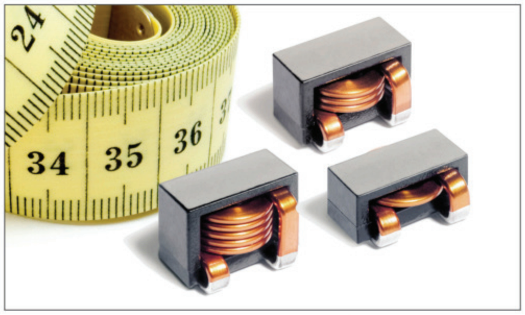


Figure 2. E-Core Inductor with Flat Wire

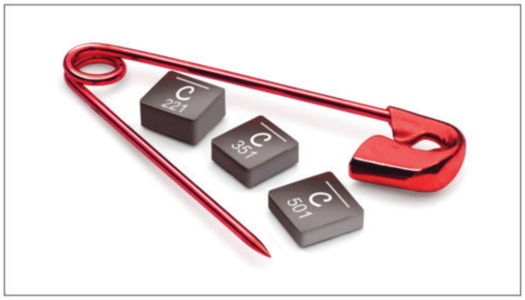


Figure 3. Molded inductors are mechanically rugged and magnetically shielded for use in high density circuits

DC-DC Converter Requirements

Simply stated, the function of a DC-DC converter is to provide a stable dc output voltage from a given input voltage. The converter is typically required to regulate the dc output voltage given a range of load currents drawn and/or range of input voltage applied. Ideally the dc output is to be "clean", that is with ripple current or voltage held below a specified level. Furthermore, the load power is to be delivered from the source with some specified level of efficiency. Power inductor selection is an important step to achieving these goals.

Power Inductor Parameters

Inductor performance can be described by a relatively few numbers. Table 1 shows a typical data sheet excerpt for a surface mount power inductor intended for DC-DC converters.

Part number	L ±20%[a] (µH)	DCR max (mOhms)	SRF typ (MHz)	Isat[b] (A)	Irms[c] (A)
XAL4020-102	1.0	14.6	79	8.7	9.6

a. Inductance tested at 1 MHz, 0.1 Vrms
b. Inductance drop = 30% typ. at Isat
c. For 40° C temperature rise typ. at Irms
d. All parameters tested at 25° C.

Table 1. Typical Inductor Catalog Excerpt[2]

To use the ratings properly, one must understand how they were derived. Since it is not practical for a data sheet to show performance for all possible sets of operating conditions, it is important to have some understanding of how the ratings would change with different operating conditions.

Inductance (L)

Inductance is the main parameter that provides the desired circuit function and is the first parameter to be calculated in most design procedures. Inductance is calculated to provide a certain minimum amount of energy storage (or volt-microsecond capacity) and to reduce output current ripple. Using less than the calculated inductance causes increased ac ripple on the dc output. Using much greater or much less inductance may force the converter to change between continuous and discontinuous modes of operation.

Tolerance

Fortunately most DC-DC converter applications do not require extremely tight tolerance inductors to achieve these goals. It is, as with most components, cost effective to choose standard tolerance parts and most converter requirements allow this. The inductor in Table 1 is shown specified at ±20% which is suitable for most converter applications.

Test Conditions

- Voltage. The inductance value rating should note the applied frequency and test voltage. Most catalog inductance ratings are based on "small" sinusoidal voltages. This is the easiest and most repeatable method for the inductor supplier, and suitably indicates the inductance for most applications.
- Wave shape. The use of sinusoidal voltage is a standard instrumentation test condition, which usually serves quite well to ensure that the inductance value calculated from the design equations is delivered.
- Test Frequency. Most power inductors do not vary dramatically between 20 kHz and 500 kHz so a rating based on 100 kHz is quite often used and suitable. It must be remembered that inductance eventually decreases as frequency increases. This can be due to the frequency roll off characteristic of the core material used or it may be due to the self-resonance of the winding inductance resonating with its self capacitance. As most converters operate in the 50 kHz to 500 kHz range, 100 kHz has been a suitable standard test frequency. As switching frequencies increase to 500 kHz, 1 MHz, and above, it will be more important to consider ratings based on the actual application frequency.

Definitions

L – Inductance The primary functional parameter of an inductor. This is the value that is calculated by converter design equations to determine the inductors ability to handle the desired output power and control ripple current.·

DCR – DC Resistance The resistance in a component due to the length and diameter of the winding wire used.

SRF – Self Resonant Frequency The frequency at which the inductance of an inductor winding resonates naturally with the distributed capacitance characteristic of that winding.

Isat – Saturation Current The amount of current flowing through an inductor that causes the inductance to drop due to core saturation.·

Irms – RMS Current The amount of continuous current flowing through an inductor that causes the maximum allowable temperature rise.

Resistance

DC Resistance (DCR)

DCR is simply a measure of the wire used in the inductor. It is based strictly on the wire diameter and length. Normally this is specified as a "max" in the catalog but can also be specified as a nominal with a tolerance. This second method can be a little more instructive by giving a better indication of the nominal or expected resistance, but also may unnecessarily tighten the specification as almost always no harm is done by a part having too little resistance.

DCR varies with temperature in the same manner as the resistivity of the winding material, typically copper. It is important that the DCR rating makes note of the ambient test temperature. The temperature coefficient of resistance for copper is approximately +0.4% per degree C[3]. So the part shown rated at 0.009 Ohms max would have to have a corresponding rating of 0.011 Ohms max at 85°C, only a 2 milliOhm difference in this case, but a total change of about 25%. The expected DCR versus temperature is shown in Figure 4.

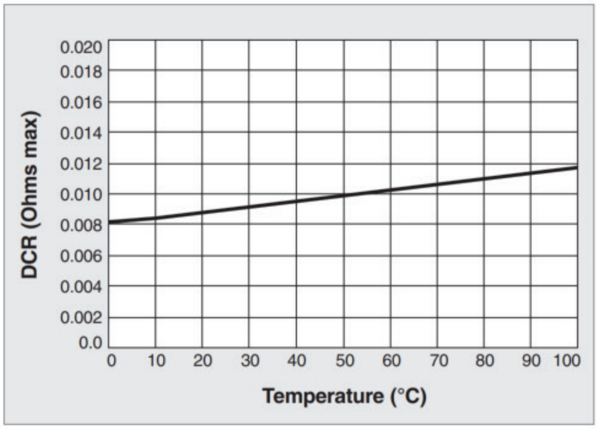


Figure 4. Expected DCR Based on 0.009Ω Max at 25°C

AC Resistance

This is a parameter that is not commonly shown on inductor data sheets and is not typically a concern unless either the operating frequency or the ac component of the current is large with respect to the dc component.

The resistance of most inductor windings increases with operating frequency due to skin effect. If the ac or ripple current is relatively small compared to the average or dc current then the DCR gives a good measure of the resistive loss to be expected. The skin effect varies with wire diameter and frequency[3], so to include this data would require a full frequency curve for each inductor listed in a catalog.

This has not been necessary for most applications working below 500 kHz. As can be seen from Figure 5 the ac resistance does not become comparable to the dc resistance at frequencies below about 200 kHz. And even above that frequency the ac

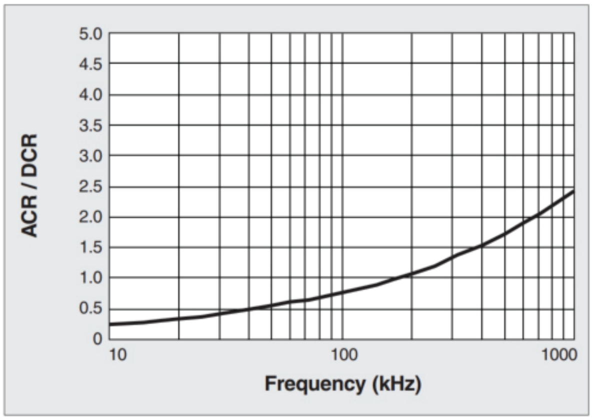


Figure 5. ACR/DCR for #22 AWG Round Copper Wire

resistance will not be an issue if the ac current is not large compared to the dc component. Nevertheless at frequencies above 200-300 kHz it is recommended to ask the supplier for loss versus frequency information to supplement the published information.

The designer should try to choose the component that has the largest possible resistance if the size of the component is to be minimized. Typically to reduce the DCR means having to use larger wire and probably a larger overall size. So optimizing the DCR selection means a tradeoff of power efficiency, allowable voltage drop across the component, and component size.

Self Resonant Frequency (SRF)

Every inductor winding has some associated distributed capacitance which, along with the inductance forms a parallel resonant tank circuit with a natural self-resonant frequency. For most converters it is best to operate the inductors at frequencies well below the SRF. This is usually shown in the inductor data as a “typical” value.

Current Rating

Current Rating is perhaps the rating that causes the most difficulty when specifying a power inductor. Current through a DC-DC converter inductor is always changing throughout the switching cycle and may change from cycle to cycle depending on converter operation, including temporary transients or spikes due to abrupt load or line changes. This gives a constantly changing current value with sometime a very high peak-to-average ratio. It is the peak-to-average ratio that makes specification difficult. If one takes the highest possible instantaneous peak current and looks for an inductor with this "current rating" the inductor is likely to be overkill for the application, yet if one looks for a current rating for the average current, the inductor may not perform well when passing the peak current. The way to address this problem is to look for an inductor that has two current ratings, one to deal with possible core saturation from the peak current and one to address the heating that can occur due to the average current.

Saturation Current

One effect of current through an inductor is core saturation. Frequently DC-DC converters have current wave shapes with a dc component. The dc current through an inductor biases the core and can cause it to become saturated with magnetic flux. The designer needs to understand that when this occurs the inductance drops and the component no longer functions as an inductor. Figure 6 shows a typical L vs current curve for a gapped ferrite core. It can be seen that this curve has a "knee" as the inductor moves into the saturation region. Definition of where saturation begins is therefore

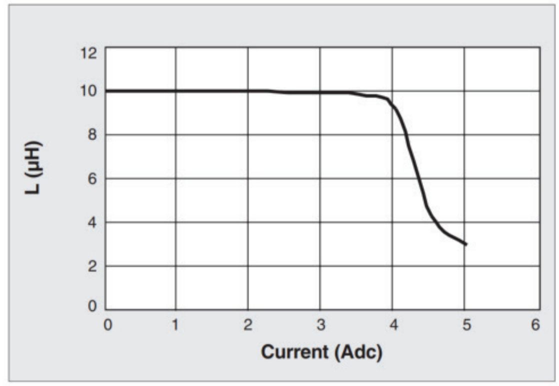


Figure 6. L vs DC Bias Current for Coilcraft DO3316P-103

somewhat arbitrary and must be defined. In the example of Table 1, saturation is defined at the point at which the inductance drops by 10%. Definitions in the range of 10-20% are common, but it should be noted some inductor catalogs may use figures of 50% inductance drop. This increases the current rating but may be misleading as far as the usable range of current is concerned.

Inductor core saturation can often be observed directly in the converter current waveform where di/dt is inversely proportional to inductance. As inductance drops due to core saturation, the current slope increase rapidly. This can cause noise and damage to other components.

If the inductor is operated at currents only slightly exceeding the saturation current rating, however, the problem may not be so dramatic. In many cases a slight rise in the slope of the current waveform is acceptable. Despite the potential pitfalls, it is typically desirable to operate with current peaks near the saturation rating because this allows the smallest possible inductor to be chosen. Increasing the saturation current rating typically means using a larger size component or selecting a smaller inductance value in the same size.

RMS Current

The second major effect of current is component self-heating. The RMS current is used to give a measure of how much average current can continuously flow through the part while producing less than some specified temperature rise. In this case the data sheets almost always provide a rating based on application of dc or low frequency ac current, so this does not include heating that may occur due to skin effect as mentioned earlier or other high frequency effects. The current rating may be shown for a single temperature rise point as in the example, or some suppliers provide helpful graphs of temperature rise versus current or factors that can be used to calculate temperature rise for any current.

The Irms rating should include the ambient temperature at which it was measured. Normally an inductor specification includes an operating temperature range. This is the range of ambient temperature environment within which the inductor is expected to be used. Temperature rise due to self heating may cause the inductor to be at a temperature higher than the rated range. This

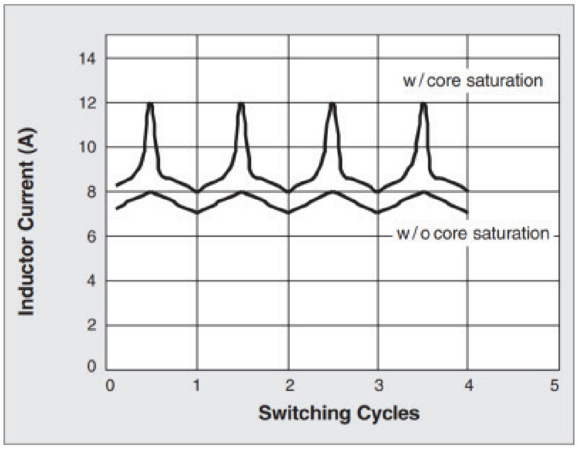


Figure 7. Inductor Current Waveform With and Without Core Saturation.

is normally acceptable provided the insulation ratings are not exceeded. Most inductors presently use at least 130°C or 150°C insulation types.

As with other parameters it is important to know the inductor temperature rise so this can be traded off with other parameters when making design choices. If lower temperature rise is desired, a larger size component is most likely the answer.

Conclusion

It can be seen that inductors for DC-DC converters can be described by a small number of parameters. However each rating may be thought of as a "snapshot" based on one set of operating conditions which may need to be augmented to completely describe expected performance in application conditions. Table 2 summarizes the ratings that should appear in a power inductor data sheet.

Parameter	Rating Should Include
Inductance	• Nominal value • Tolerance • Test frequency • Test voltage • Ambient test temperature
DCR: The wire resistance.	• Nominal with tolerance or max value • Ambient test temperature
SRF: The frequency at which the winding self capacitance resonates with the inductance.	• Typical or nominal value
Isat: The current at which inductance drops due to core saturation.	• Minimum or typical value. • Definition of saturation.
Irms: The current which causes a specified amount of temperature rise.	• Minimum value. • Ambient test temperature.

Table 2. Summary of Important Inductor Ratings

References

1. *Switchers Made Simple, an Expert System for the Automated Design of DC to DC Converters using Simple Switcher Power Converters* Version 4.1, National Semiconductor.

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TECHNICAL ARTICLE

Choosing Inductors for Energy Efficient Power Applications

Energy efficiency can be as much about the inductors as the circuit topology.

In high frequency DC-DC converters, inductors filter out the AC ripple current superimposed on the DC output. Whether the converter steps the voltage down – buck – or steps the voltage up – boost – or both up and down – SEPIC, the inductor smooths the ripple to provide a pseudo-DC output.

For battery powered applications, battery life is extended by improving the efficiency of the entire power supply circuit, and inductor efficiency is often a major consideration in the design. Careful consideration of inductor efficiency can mean the difference between having your battery work when you need it and having to stop in the middle of an important task to plug it into a charger.

Inductor efficiency is highest when the combination of core and winding losses are the lowest. Therefore, the goal of highest efficiency is met by selecting an inductor that provides sufficient inductance to smooth out the ripple current while simultaneously minimizing losses. The inductor must pass the current without saturating the core or over-heating the winding.

Accurately predicting core and winding loss of an inductor can be fairly complicated. Core loss depends on several factors, such as peak-peak ripple current, ripple current frequency, core material, core size, and turn count. The required ripple current and ripple current frequency are application-dependent, while the core material, core size, and turn count are inductor-dependent.

The most commonly-used equation to characterize core loss is the Steinmetz equation: $P_{core} = K(f)^x(B)^y$
Where:
P_{core} = power loss in the core
K, x, y = core material constants
F = frequency
B = flux density

This equation shows that core loss depends on frequency (f) and flux density (B). Flux density depends on ripple current, so both are application-dependent variables. It also shows that the core loss is inductor-dependent, where the core material determines the K, x, and y constants. Note that flux density is also a function of the core area (Ae) and the number of turns (N), therefore core loss is both application-dependent and inductor-dependent

By comparison, DC winding loss is simple to calculate: $P_{dc} = I_{dc}^2 \times DCR$

Where:
P_{dc} = DC power in Watts dissipated
I_{dc} = Effective DC (rms) value of the inductor current.
DCR = DC resistance of the inductor winding

AC winding loss is more complicated and may include the effects of increased resistance at higher frequency due to both skin effect and proximity effect. ESR (effective series resistance) or ACR (AC resistance) curves may show some of the increased resistance at higher frequency, however, these curves are typically made at very low current levels, so they do not capture current-dependent (core) loss. They are also subject to possible misinterpretation.

For example, consider the ESR vs frequency curve shown in Figure 1. An initial observation indicates that the resistance looks very high above 1 MHz. This would strongly suggest that this part cannot or should not be used at that frequency due to the expected very high loss due to the ESR. However, it has been observed that parts with curves like this have performed very well in actual converters – much better than would be suggested by these curves.

Consider the following example:
Assume a converter is needed to provide an output of 5 V at 0.3 A (1.5 Watts). We will use a 10 µH Coilcraft inductor with a typical ESR vs frequency

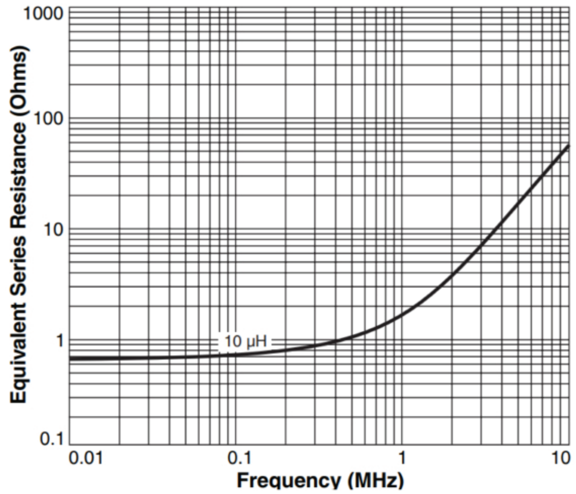


Figure 1. ESR vs Frequency

as shown in Figure 1. If the converter operates at 250 kHz, we see from the graph that the ESR, which includes both ac and dc resistance is approximately 0.8 Ohms.

For a buck converter, the average inductor current equals the load current, 0.3 A.
We can calculate the loss in the inductor:

$$I^2R = (0.3\ A)^2 \times (0.8\Omega) = 0.072\ W.$$

0.072 W ÷ 1.5 W = approx 5% of output power is lost in the inductor.

However, if we were to run the same converter at 5 MHz, we can see from the ESR curve that R is between

$$I^2R = (0.3\ A)^2 \times (10\Omega) = 0.9\ W$$

10 Ohms and 20 Ohms. If we even assume R = 10 Ohms, then the power loss in the inductor should be:
0.9 W ÷ 1.5 W = 60% of the output power is lost in the inductor!

Based on this very simple example it would seem obvious that a designer should not choose to use a component like this.

It has been observed that converters, in fact, often achieve better performance than the ESR curves predict. The following explanation illustrates why.

Figure 2 shows a very simplified version of a possible buck converter waveform, with continuous conduction and the ripple current is relatively small compared to the average current.

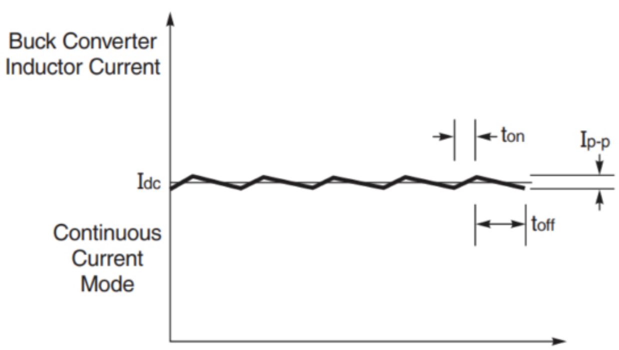


Figure 2. Ideal Converter Waveform with Small Ripple Current

Let's assume that the ripple current peak-peak is about 10% of the average current. From the previous example
this means:
I_{dc} = 0.3 A
I_{p-p} = 0.03 A

In order to predict the inductor losses correctly, this must be separated into two components. For the low frequency or dc loss, we use the low frequency resistance (effectively DCR), which we can see from the graph is 0.7 Ohms.

The current is the rms value of the load current plus the ripple current. In this case the ripple current is small, so the value is approximately equal to the dc load current.

Low frequency loss = Idc^2R = $(0.3\ A)^2 \times (0.7\Omega)$ = 0.063 W

To get the total loss, we must add that to the high frequency loss, which is I^2R. In this case the R is the ESR and the I is the rms value of the ripple current only.

Approximate rms ripple current:
At 250 kHz the ac loss would be: $(0.0087\ A)^2 \times (0.8\ \Omega)$ = 0.00006 W.

Therefore, at 250 kHz, we predict the total inductor loss is 0.063 W + 0.00006 W = 0.06306 W.

We see that operating at 250 kHz predicts only slightly more loss (less than 1%) than predicted simply by the DCR.

Now, let's look at the same example at 5 MHz. The low frequency loss is still the same 0.063 W.

The ac loss calculation must use the ESR, which was previously estimated at 10 Ohms:
$(0.0087\ A)^2 \times (10\ \Omega)$ = 0.00076 W.

So, the total inductor loss at 5 MHz: 0.063 W + 0.00076 W = 0.06376 W.

This loss is more significant, with a predicted loss of about 1.2% greater than DCR loss, but is not nearly the 0.9 W originally predicted by multiplying the ESR by the entire load current.

Also, this example is not exactly fair, because we wouldn't use the same inductor value at 5 MHz as we would at 250 kHz. We would use a much smaller L and therefore we would get a much smaller DCR.

$$I_{p\text{-}p} \div 2\sqrt{3}\ ) = 0.03\ A \div 3.464 = 0.0087\ A$$

In summary, the inductor loss must be calculated by a combination of the DCR and ESR, and for a continuous current mode converter in which the ripple current is small compared to the load current, the losses will be reasonable.

In typical applications, ripple current is kept to approximately 40% of the load current or less. Regardless of ripple content, ESR curves do not capture current-dependent core loss at higher current, and **total** inductor loss determines the overall inductor efficiency.

Therefore, inductor manufacturers optimize inductor efficiency by selecting low loss materials and designing inductors for minimal total loss. The use of rectangular "flat" wire may provide the lowest DCR in a given size to minimize DC loss. Improvements in core materials have led to inductors with very low AC core loss at high frequency resulting in higher inductor efficiency.

For example, Coilcraft's industry-leading XGL Family of molded power inductors are optimized for high frequency, high peak current applications. These offer soft-saturation, while also providing the lowest AC loss at frequencies of 2 MHz and higher. They also have extremely low DCR for their size.

Figure 3 shows the inductance vs current characteristics of the 2.2 µH value in the XGL, XEL, XAL, and XFL Series. The XGL, XEL, and XAL series are clearly the best choice for holding inductance at around 3 A or higher current. Table 1 compares the DCR and Isat of these inductors.

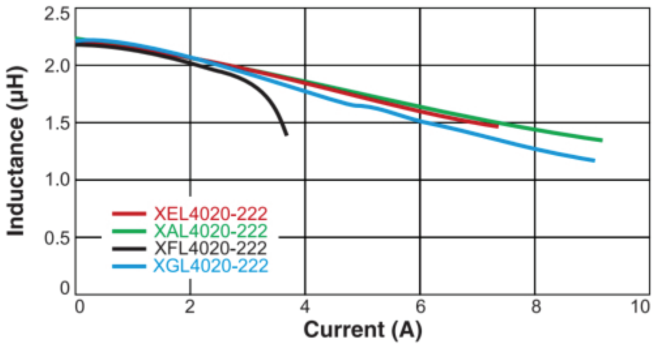


Figure 3. Comparing L vs I of XAL, XEL XFL and XGL 2.2 µH inductors

	L nom	DCR typ	Isat (30%)
XGL4020-222	2.2 µH	19.5 mOhms	5.9 A
XEL4020-222	2.2 µH	35.2 mOhms	5.9 A
XAL4020-222	2.2 µH	35.2 mOhms	5.6 A
XFL4020-222	2.2 µH	21.4 mOhms	3.7 A

Table 1. Comparing XAL, XEL and XFL

Figure 4 (shown on following page) compares the AC loss and total loss of the same inductors at 2 MHz. The XGL utilizes an innovative construction that exceeds all previous designs, resulting in a combination of the lowest DC and AC losses. This makes the XGL Family the best choice for high frequency power converter applications that must withstand high peak current with lowest DC and AC losses.

To speed up the design process for engineers selecting inductors, Coilcraft has developed tools that calculate measurement-based core and winding loss for each possible application condition.

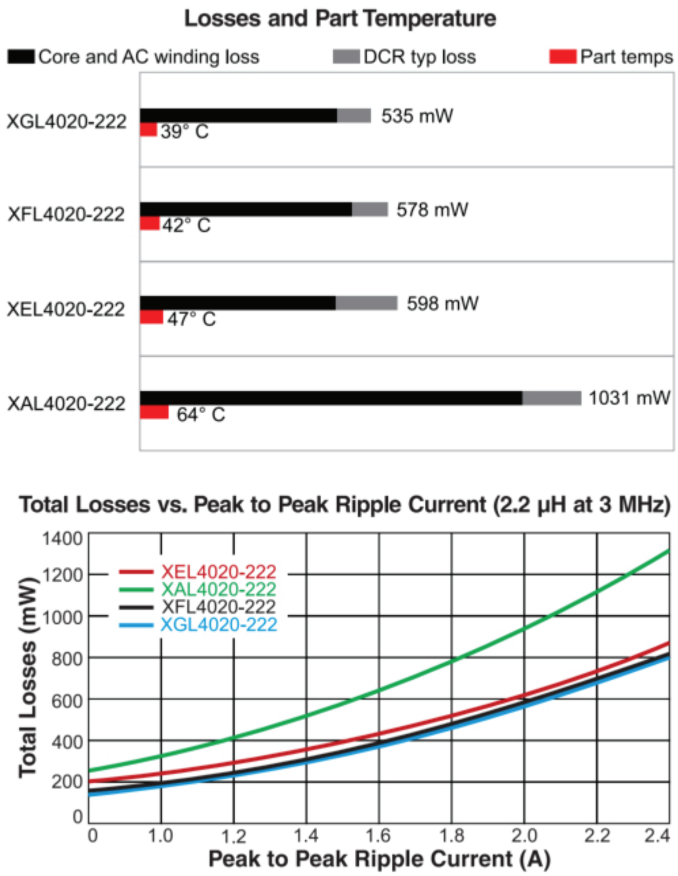


Figure 4. Comparing AC Losses and Total Losses of XAL, XEL, XFL, and XGL at 2 MHz

The results from these tools include current-dependent and frequency-dependent core and winding loss, eliminating the need to request proprietary inductor design information, such as core material, Ae, and number of turns, and the need to perform hand calculations.

If your application is a DC-DC converter, the Coilcraft DC-DC Optimizer Tool calculates the inductance value, peak current, and peak-peak current requirements based on your operating conditions and amount of AC ripple current you choose. It then feeds this information into our Power Inductor Finder tool to display a list of inductors that may meet these requirements.

The list includes the inductance at peak current, current rating, total losses, and resulting part temperature for each inductor listed.

If you already know the inductance value and current ratings required for your application, enter this information directly into the Power Inductor Finder. The results include core and winding (total) loss and saturation current ratings for each inductor, to verify that the inductance will remain close to the design requirement at the peak current condition.

The tool may also be used to graph the inductance vs current behavior to compare traditional hard-saturating inductors to soft saturation types. To select the highest efficiency inductor, the results can be first sorted by total loss. Multiple sorts allow selection by multiple parameters.

Inductor loss is closely related to core size and wire size. In many cases, lowest loss corresponds to larger part size, or it corresponds to using a hard-saturation core material. As with any design, there may be compromises that require analyzing trade-offs in size or inductance at peak current vs efficiency. Having all of the inductor information in a complete list that allows multiple sorting facilitates such an analysis.

Conclusion

Designing for highest efficiency performance requires selection of inductors with the lowest total loss at application conditions. Calculating total loss can be complicated, but these calculations are built into the Coilcraft power magnetics tools, making selection, comparison, and analysis as simple as possible.

References

XGL, XEL, XAL, or XFL? – Which Molded Power Inductor is Right for You?, Coilcraft web page:
https://www.coilcraft.com/en-us/other/xal-or-xfl-or-xgl/

Coilcraft DC-DC Optimizer, Coilcraft website,
https://www.coilcraft.com/en-us/tools/dc-dc-optimizer/#/search

Coilcraft Power Inductor Finder and Analyzer Tool, Coilcraft website,
https://www.coilcraft.com/en-us/tools/power-inductor-finder/#/search

TECHNICAL ARTICLE

Selecting Inductors to Drive LEDs

LED lighting is an exciting and fast growing application. LEDs can provide low cost, reliable lighting for a wide variety of applications ranging from architectural and automotive to signage and handheld devices. The designer faces the challenge of choosing from a vast array of LED manufacturers and device styles. Equally challenging can be the selection of components for the LED driver circuit. Fortunately, powerful tools are available that greatly facilitate the power inductor selection.

Since LED applications can use LEDs individually as well as parallel or serial arrays, the driver circuit may need to be a voltage step-up, step-down, or both. The Coilcraft DC-DC Optimizer tool can be used to select the inductor for all of these driver circuit configurations.

Buck Converter Example

This example demonstrates the use of the **Coilcraft DC-DC Optimizer** tool to select the inductor for a Texas Instruments Buck LED driver reference design based on the LED Driver TPS92515-Q1. This design is for a high-brightness LED and features a wide input voltage, PWM dimming, and an analog dimming capability.

The design has a switching frequency of 125 kHz and an input voltage of 5.5 to 65 V. Electrical performance specifications are:

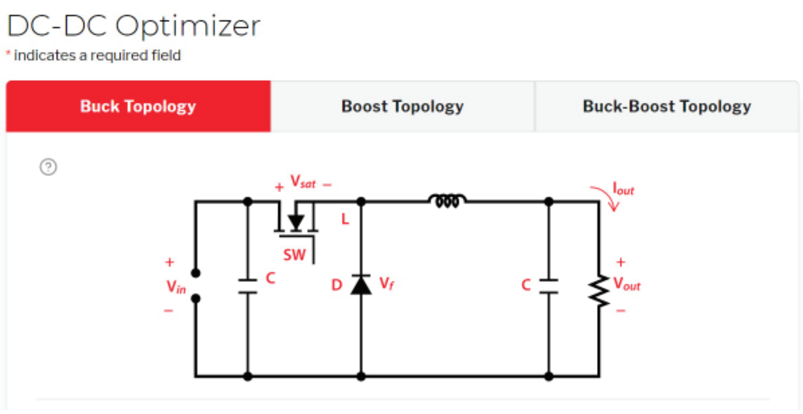
Fsw = 125 kHz

Vin = 5.5 to 65 Vdc

Vo = Vled = 22 V

Io = 1000 mA

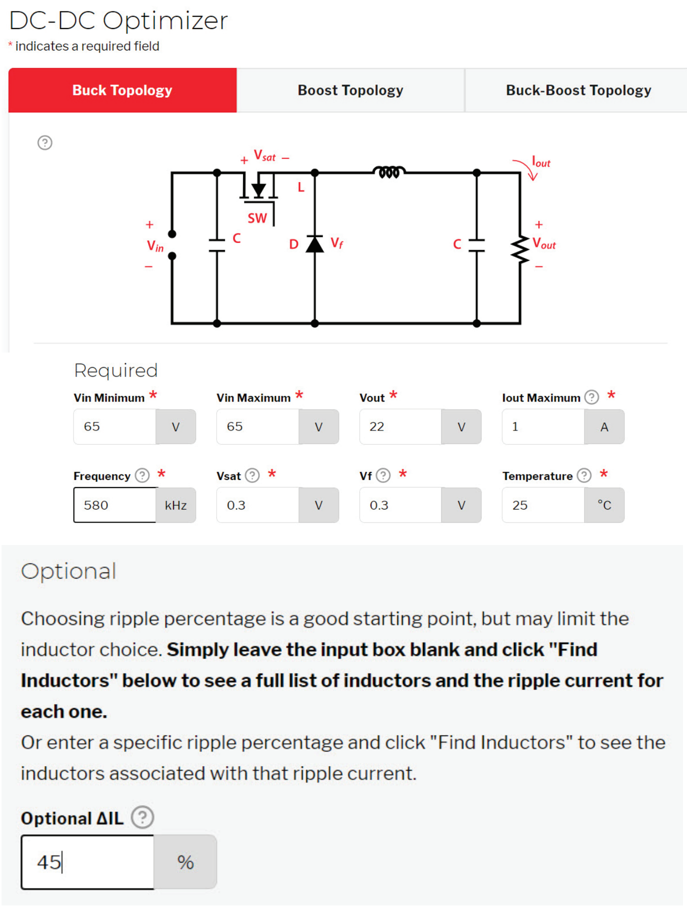
This is all the information needed to proceed to the **Coilcraft DC-DC Optimizer** tool. The first step is to identify **Buck** as the driver circuit topology.



Company	Part Number	Vf (V)	Io (mA)	Color	Url
Nichia	NJSW170C	3.0	350	White	www.nichia.com
Osram Opto	KW DPLS31.SB	3.05	120	White	www.osram.com
Everlight	A09K-C71501H-AM	3.1	150	Cool White	www.everlight.com
Samsung	SPMWHT346EA3	3.5	140	White	www.samsung.com/led/
Seoul Semiconductor	SZ8-Y11-W0	2.8	150	White	www.seoulsemicon.com
Cree	JE2835 3V	3.0	150	White	www.cree.com

Table 1. Typical White LEDs

The second step requires inputting the operating parameters: Vin, Vout, Iout, switching frequency and the selection of the allowed peak-peak ripple current.



Note the input voltage as well as the output current and voltage are specified as part of the design requirement. The switching frequency may represent some design freedom if a driver IC is not yet selected, but generally the only degree of freedom in selecting the inductor value is the amount of ripple current to be allowed.

As the default setting, the **DC-DC Optimizer** tool calculates the ripple current for each inductor in the tool. As an option, a specific ripple percentage can be entered into the tool. In this example, the design uses a 1 Amp solution with 45% peak-peak inductor ripple current.

From these inputs, the Coilcraft DC-DC Optimizer tool calculates the resulting ripple current for each inductor in the tool within a range of the entered ripple current.

Part Number	L nominal (µH)	L actual at Ipeak (µH)	I peak (A)	ΔIL%	Isat (A)	Irms (A)	DCR Typ @ 25°C (mΩ)	Total losses (mW)	Part temp. (°C)	Temp. rating	Length (mm)	Width (mm)	Height (mm)	Mount	Shielded
XFL6060-473	47.0	42.9	1.3	57%	1.8	3.7	68.4	126	31°C	165°C	6.76	6.56	6.1	SM	Yes
MSS7348-473	47.0	36.1	1.3	60%	1.4	1.6	132	788	118°C	125°C	7.3	7.3	4.8	SM	Yes
XAL7050-473	47.0	43.7	1.3	56%	3.5	3.5	105	825	51°C	165°C	8.0	7.7	5.0	SM	Yes
LPS8045B-473	47.0	44.6	1.3	56%	1.8	1.5	153	210	49°C	125°C	8.08	8.08	4.7	SM	Yes
LPS8045B-683	68.0	64.0	1.2	39%	1.4	1.4	193	229	51°C	125°C	8.08	8.08	4.7	SM	Yes
XAL8080-473	47.0	45.1	1.3	55%	4.4	4.7	73.3	365	34°C	165°C	8.8	8.3	8.0	SM	Yes
MSS1038-473	47.0	43.1	1.3	57%	2.2	2.2	115	382	52°C	125°C	10.5	10.2	4.0	SM	Yes
MSS1038-563	56.0	51.5	1.2	48%	2.0	1.9	162	377	52°C	125°C	10.5	10.2	4.0	SM	Yes
MSS1038-683	68.0	61.1	1.2	40%	1.8	1.8	192	375	51°C	125°C	10.5	10.2	4.0	SM	Yes
MSS1038-823	82.0	73.2	1.2	34%	1.6	1.5	235	391	55°C	125°C	10.5	10.2	4.0	SM	Yes

With multiple results, the user may optimize the inductor selection based on criteria specific to the application. The tool allows a quick sort of the results by user-selected parameters. For example, for a handheld mobile device or backlight display, component height may be the most important criterion.

Part Number	L nominal (µH)	L actual at Ipeak (µH)	I peak (A)	ΔIL%	Isat (A)	Irms (A)	DCR Typ @ 25°C (mΩ)	Total losses (mW)	Part temp. (°C)	Temp. rating	Length (mm)	Width (mm)	Height (mm)	Mount	Shielded
DO3308P-473	47.0	45.1	1.3	55%	1.3	1.0	288	340	72°C	125°C	12.95	9.4	3.0	SM	No
MSS1038-473	47.0	43.1	1.3	57%	2.2	2.2	115	382	52°C	125°C	10.5	10.2	4.0	SM	Yes
MSS1038-563	56.0	51.5	1.2	48%	2.0	1.9	162	377	52°C	125°C	10.5	10.2	4.0	SM	Yes
MSS1038-683	68.0	61.1	1.2	40%	1.8	1.8	192	375	51°C	125°C	10.5	10.2	4.0	SM	Yes
MSS1038-823	82.0	73.2	1.2	34%	1.6	1.5	235	391	55°C	125°C	10.5	10.2	4.0	SM	Yes
MSS1038T-473	47.0	44.5	1.3	56%	2.2	2.2	115	371	52°C	165°C	10.5	10.2	4.0	SM	Yes
MSS1038T-563	56.0	51.9	1.2	48%	2.0	1.9	162	374	52°C	165°C	10.5	10.2	4.0	SM	Yes
MSS1038T-683	68.0	63.3	1.2	39%	1.8	1.8	192	365	50°C	165°C	10.5	10.2	4.0	SM	Yes
MSS1038T-823	82.0	74.3	1.2	33%	1.6	1.5	235	386	54°C	165°C	10.5	10.2	4.0	SM	Yes
LPS8045B-473	47.0	44.6	1.3	56%	1.8	1.5	153	210	49°C	125°C	8.08	8.08	4.7	SM	Yes

If extra margin in the current rating to prevent inductor saturation is preferred, sorting by Isat is recommended. More importantly, you can sort by total loss (DC loss + AC loss) to select an inductor that provides the best power efficiency for your application.

Part Number	L nominal (µH)	L actual at Ipeak (µH)	I peak (A)	ΔIL%	Isat (A)	Irms (A)	DCR Typ @ 25°C (mΩ)	Total losses (mW)	Part temp. (°C)	Temp. rating	Length (mm)	Width (mm)	Height (mm)	Mount	Shielded
DO5040H-473	47.0	47.0	1.3	54%	7.8	3.7	46.8	56	28°C	125°C	18.54	15.24	12.0	SM	No
MSS1583-473	47.0	46.9	1.3	54%	7.3	3.7	48.0	149	34°C	125°C	15.5	15.5	8.6	SM	Yes
DO5040H-683	68.0	68.0	1.2	37%	6.7	3.4	60.3	66	29°C	125°C	18.54	15.24	12.0	SM	No
MSS1583-683	68.0	67.8	1.2	37%	6.0	3.4	61.0	126	32°C	125°C	15.5	15.5	8.6	SM	Yes
MSS1210-473	47.0	46.6	1.3	54%	5.8	3.0	48.0	140	38°C	125°C	12.3	12.3	10.2	SM	Yes
MSS1278T-473	47.0	46.8	1.3	54%	5.7	2.9	72.3	173	36°C	165°C	12.3	12.3	8.05	SM	Yes
SER2211-473	47.0	46.9	1.3	54%	5.6	10.6	8.9	112	29°C	125°C	22.5	19.2	10.5	SM	Yes
MSS1278-473	47.0	46.8	1.3	54%	5.3	2.9	72.3	165	36°C	125°C	12.3	12.3	8.05	SM	Yes
MSS1278T-563	56.0	55.8	1.2	45%	5.3	2.7	80.2	159	36°C	165°C	12.3	12.3	8.05	SM	Yes
MSS1278-563	56.0	55.7	1.2	45%	4.9	2.7	80.2	153	35°C	125°C	12.3	12.3	8.05	SM	Yes

Part Number	L nominal (µH)	L actual at Ipeak (µH)	I peak (A)	ΔIL%	Isat (A)	Irms (A)	DCR Typ @ 25°C (mΩ)	Total losses (mW)	Part temp. (°C)	Temp. rating	Length (mm)	Width (mm)	Height (mm)	Mount	Shielded
DO5040H-473	47.0	47.0	1.3	54%	7.8	3.7	46.8	56	28°C	125°C	18.54	15.24	12.0	SM	No
DO5040H-683	68.0	68.0	1.2	37%	6.7	3.4	60.3	66	29°C	125°C	18.54	15.24	12.0	SM	No
SER2211-473	47.0	46.9	1.3	54%	5.6	10.6	8.9	112	29°C	125°C	22.5	19.2	10.5	SM	Yes
DO3340P-473	47.0	47.0	1.3	54%	3.8	1.6	99.0	121	35°C	105°C	12.95	9.4	11.43	SM	No
MSS1583-683	68.0	67.8	1.2	37%	6.0	3.4	61.0	125	32°C	125°C	15.5	15.5	8.6	SM	Yes
XFL6060-473	47.0	42.9	1.3	57%	1.8	3.7	68.4	126	31°C	165°C	6.76	6.56	6.1	SM	Yes
MSS1210-683	68.0	67.3	1.2	38%	4.9	2.8	68.0	132	35°C	125°C	12.3	12.3	10.2	SM	Yes
MSS1210-473	47.0	46.6	1.3	54%	5.8	3.0	48.0	140	38°C	125°C	12.3	12.3	10.2	SM	Yes
MSS1210H-683	68.0	67.6	1.2	37%	3.6	3.4	56.0	144	34°C	165°C	12.3	12.3	10.2	SM	Yes
MSS1583-473	47.0	46.9	1.3	54%	7.3	3.7	48.0	149	34°C	125°C	15.5	15.5	8.6	SM	Yes

The Coilcraft DC-DC Optimizer tool features the flexibility to help the user optimize the inductor selection based on the criteria most important to that application.

Conclusion

LED lighting is a growing and exciting application area and Coilcraft design tools can guide the designer quickly and easily to inductors best suited to a variety of applications.

TECHNICAL ARTICLE

New Converters Deserve (and get) Better Inductors

Benefits abound from low DCR inductors.

New inductors are introduced all the time. In such an established industry as ours, it is quite natural that many new products represent small, evolutionary improvements or solve unique problems. Occasionally, however, major generational breakthroughs do come along that challenge designers into new ways of thinking in order to take full advantage. This article will examine the latest game-changing inductor designs and how creative thinking designers go beyond the datasheet to make the proper inductor choice for the best converter design.

Inductors remain at the heart of power electronics. Selecting the correct inductor optimizes the reliability, size, and operating characteristics of a power converter. The clever designer knows the process of making a proper inductor choice cannot be taken for granted and cannot easily be captured in a handbook. After all, circuit requirements change with time. The inductor we wanted yesterday is simply not the inductor we want today. Trends include simple things like switching frequency, of course, but picking the optimal inductor also changes with the advent and proliferation of GaN devices to replace silicon MOSFETs, new controllers and control schemes, as well as the need to provide tightly regulated power from ever-wider Vin sources. These things mean old rules of thumb like "choose inductance value so ripple current = 40% of load current" may simply not always apply for the converter designs of today and tomorrow.

In addition to the evolution of what we ask our inductors to do, the basic nature of inductor operation encourages the use of careful thought to choose correctly. Inductors are passive devices that are far more interesting when something active is happening. Inductor performance is always determined by the operating/excitation conditions. All key parameters are dependent on something else: current depends on inductance as di/dt = v/L, but so too inductance depends on current as determined by the B-H curve. Inductance may vary with frequency for example, and, more subtly, is also impacted by wave shape: fast-rising edges on voltage pulses drive di/dt differently than a sine wave.

New Inductors

Let's examine an example of a recent inductor development that presents a clear and immediate benefit, with even more optimization available to the designer willing to go beyond the inductor datasheet. Coilcraft's XGL family of power inductors recently raised the performance bar significantly by lowering DC resistance. Since the new inductors are drop-in replacements for previous generations, comparisons can be readily made and the immediate benefit of lower DCR can be viewed in two ways.

The lower DCR inductor can simply replace an existing one to decrease power loss and gain efficiency. For example, the very popular XEL4020-102 inductor can now be replaced with one offering lower DCR. Figure 1 shows a comparison of the specifications and the power-saving benefit of lower DC resistance. This is a simple and valuable improvement and the user has nothing to do other than drop in the new inductor and enjoy 38% more efficient current flow through the inductor.

Part number / Compare	Inductance (µH)	DCR max (mΩ)	Isat (A)	Irms (A)	Max Temp (°C)	Length (mm)	Width (mm)	Height (mm)
XGL4020-102 (Sample, Buy)	1	9	8.8	12	165	4.3	4.3	2.1
XEL4020-102 (Sample, Buy)	1	14.6	9	9.6	165	4.3	4.3	2.1

XGL4020-102: $I^2 \times R = (10\ A)^2 \times (9\ m\Omega) = 900\ mW$

XEL4020-102: $I^2 \times R = (10\ A)^2 \times (14.6\ m\Omega) = 1460\ mW$

38% power saving

Figure 1. Low DCR Power Saving

Another way to employ the value of such new inductors is to translate the high performance into a miniaturization opportunity. Figure 2 demonstrates this valuable space savings. Using the same XEL4020-102 as a starting point, the new inductor technology can provide the same DCR in a much smaller case size. Miniaturization is the top priority is many converter designs, and smaller inductor size usually enables a significantly downsized converter.

Part number / Compare	Inductance (µH)	DCR max (mΩ)	Isat (A)	Irms (A)	Max Temp (°C)	Length (mm)	Width (mm)	Height (mm)
XGL3520-102 (Sample, Quote)	1	14.8	5.4	10.1	165	3.65	3.35	2
XFL4020-102 (Sample, Buy)	1	11.9	5.4	11	165	4.3	4.3	2.1

XGL3520-102: PCB Area = Length x Width = $12.2\ mm^2$

XEL4020-102: PCB Area = Length x Width = $18.5\ mm^2$

34% size saved

Figure 2. Low DCR Size Saving

Beyond the Datasheet

The previous examples demonstrate that inductor developments can indeed be dramatic, and can directly contribute to desirable converter designs with either higher efficiency or smaller size. When a revolutionary advanced inductor family like Coilcraft XGL is introduced, some benefits are clear from the datasheet. However, such dramatic improvements bear further investigation for even greater optimization possibilities.

The choice of inductance value results from a variety of considerations in any specific converter design. Since it is generally assumed that large inductance values come with penalties in either losses or physical size, a designer generally sets out to identify the smallest inductance value that will perform all the required functions for the converter. A typical starting point is to select an inductance value by L = v/(di/dt) such that peak-peak ripple current di = 20%-40% of the load current. This has been a traditional starting point that still works, and for a variety of reasons. Keeping relatively low ripple current certainly limits ac losses in the inductor (and other places in the powertrain). By reducing the ripple current, the peak current is reduced for all components including switches and rectifiers, impacting both losses and component reliability. In addition to losses, inductance value and ripple current also determine whether a buck converter goes into discontinuous mode at light load conditions. In the other direction, too much inductance can impact transient response. A full discussion of all these choices is beyond the scope of this article, but suffice it to say we must consider impact of inductor choice well beyond the inductor datasheet numbers.

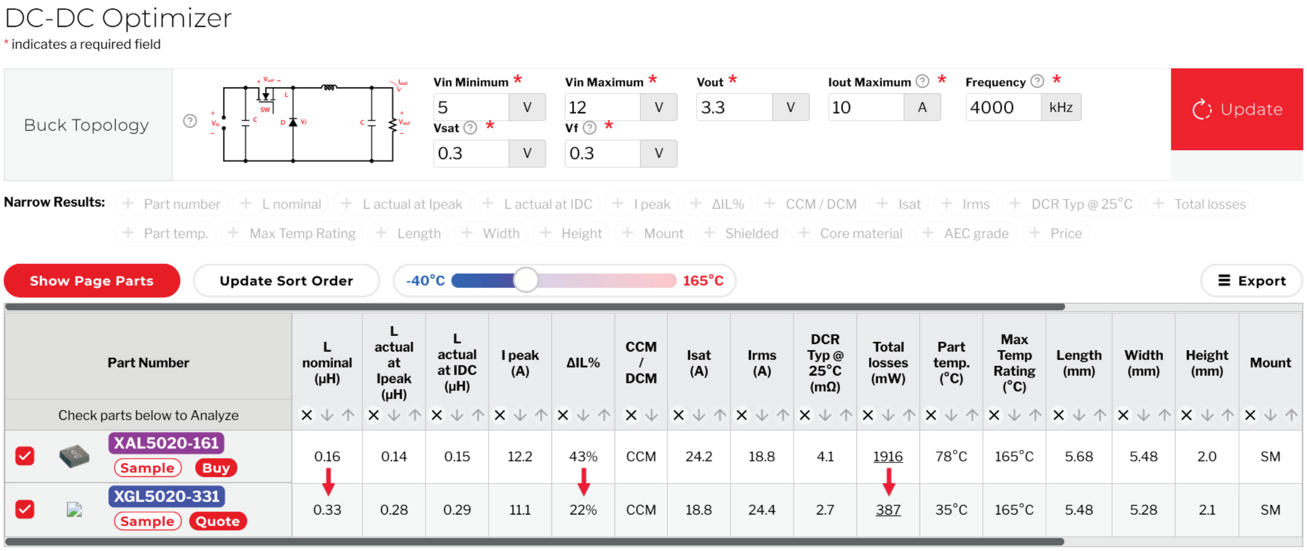
Consider a 4 MHz buck converter with the following specifications:
Vin = 12 v   Vo = 3.3 v @ 10A

For such an application, we might consider an inductor such as XAL5020-161 (160 nH). With a continuous current rating of 18.8 Arms, the inductor has plenty of current handling capability and this inductance value yields a ripple current of slightly more than 40%, roughly equivalent to our rule-of-thumb starting point.
The datasheets indicate how much more efficient it would be to use an inductor from the lower DCR XGL family, but a clever designer will also notice that a higher inductance value can be had for the same or even less DCR. Inductor losses are proportional to DCR, but are exponentially related to peak-peak current, typically by a power of 2 or more. Hence, using higher inductance can save even more power than can just a reduction of DCR. In order to see this impact of reduced ripple current, we must go beyond the datasheet and use a tool that can evaluate total loss.

	L nom	DCR typ	Irms $\Delta t = 40°C$
XAL5020-161	.160 µH	4.1 mΩ	18.8 A
XGL5020-331	.331 µH	2.7 mΩ	24.4 A

Table 1: New inductors have lower DCR for higher L

We can use the Coilcraft DC-DC Optimizer online tool to calculate a meaningful comparison of total loss for the selected XAL5020-161. The result shows that the low DCR XGL inductor lowers the total loss from over 1400 mW to less than 400 mW. The power loss saving of almost 75% greatly outpaces the DCR reduction which is on the order of 30%.



Part Number	L nominal (μH)	L actual at Ipeak (μH)	L actual at IDC (μH)	I peak (A)	ΔIL%	CCM / DCM	Isat (A)	Irms (A)	DCR Typ @ 25°C (mΩ)	Total losses (mW)	Part temp. (°C)	Max Temp Rating (°C)	Length (mm)	Width (mm)	Height (mm)	Mount
Check parts below to Analyze																
XAL5020-161 Sample Buy	0.16	0.14	0.15	12.2	43%	CCM	24.2	18.8	4.1	1916	78°C	165°C	5.68	5.48	2.0	SM
XGL5020-331 Sample Quote	0.33	0.28	0.29	11.1	22%	CCM	18.8	24.4	2.7	387	35°C	165°C	5.48	5.28	2.1	SM

Figure 3: New Inductance Choice Enhances Converter Performance

While DCR loss is certainly reduced, opting for .330 μH instead of .160 μH reduces the peak current from 12.2 A to 11.1A and the peak-peak ripple current of course by half, resulting in a major improvement in reduction of ac loss. The use of low DCR inductors to enable choice of higher inductance value has enabled a much more efficient solution while not increasing the inductor size.

Summary

These examples demonstrate that important and dramatic innovations are occurring in the inductor industry, and how innovative thinking can fully utilize new inductors to optimize converter performance.

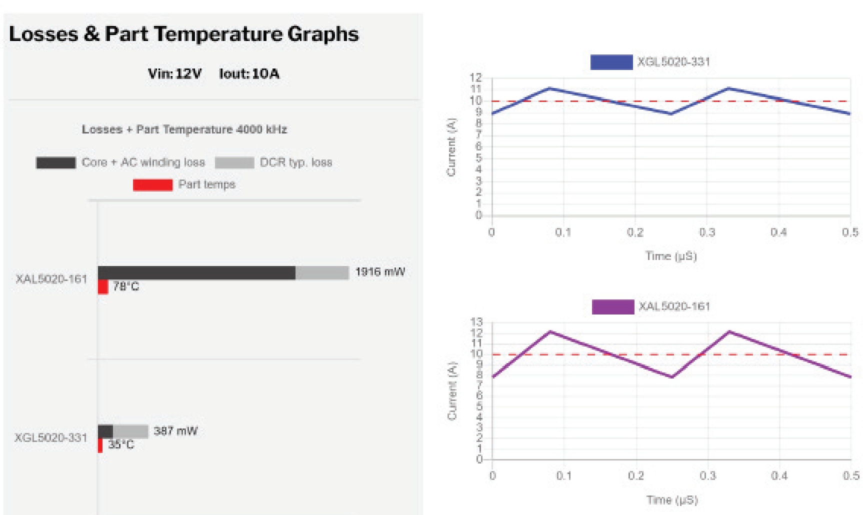


Figure 4: Advanced tools show inductor & converter performance beyond the datasheet

The Fundamentals of Power Inductors