



Specifying Inductor Values

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Introduction to Inductors

As modern electronics have continued to become more and more sophisticated, today's microcontrollers (MCUs), digital signal controllers (DSCs) and microprocessors (MPUs) are performance dependent on a steady, clean supply of DC power. This has put a lot of pressure on modern power supplies to be more efficient and provide much cleaner power for processing, data storage and networking.

A universal increase in the need for processing and connectivity is steadily increasing the need for clean and steady power for sensitive electronics. This makes choosing the correct inductor a critical part of the overall design. Engineers need to understand the power requirements of their system in order to design in an appropriately specified inductor. This paper will guide in determining an inductor's power handling and losses by reviewing the critical specs of an inductor to ensure it meets the performance characteristics of your design. The power strength of an inductor can be estimated using the data sheet specifications for current and resistance.

Topics covered:

- Maximum operating temperature
- ESR – Equivalent series resistance
- DCR – Direct current resistance
- Irms and Isat
- Power dissipated
- Current ratings
- Power losses

Maximum Operating Temperature

The maximum operating temperature of an inductor is defined by measuring the combined maximum temperature of the inductor under all conditions including ambient temperature and self-heating due to current.

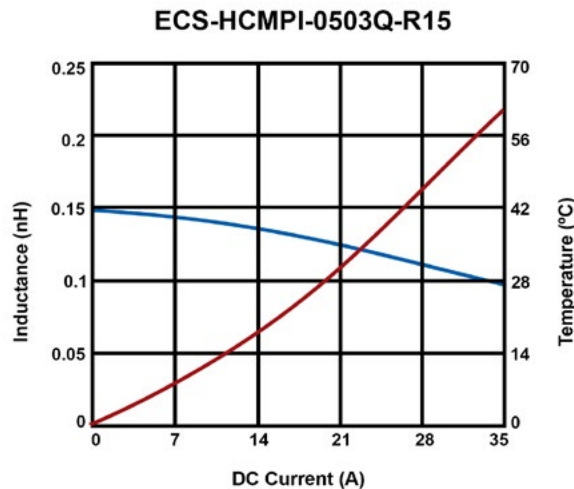
Using part number ECS-HCMPI-0503Q-R15 as an example, it lists a 0.15 μ H with a 22.2A



current rating and a 36A typical saturation current. The saturation current is the point where the magnetic field no longer increases proportionally with an increase in current. The core has become 'saturated'.

ECS-HCMPI-0503Q						
P/N	L	DCR (mΩ)	Isat (A)		Irms (A)	
	(μH)	Max	Typ.	Max.	20°C Rise	40°C Rise
ECS-HCMPI-0503Q-R15M	0.15	2.31	36.0	32.5	14.3	22.2

At ECS-HCMPI-0503Q's rated 22.2 A current we can see the L inductance will be 0.07 μH at 34°C. As the current increases we can see from the graph below, the L inductance decreases. Note in their specs at saturation current the inductance has decreased by 30% of the nominal rating of .15 μH.



Test conditions:
 Test frequency: 100 kHz / 0.1V
 Isat: Based on inductance decrease 30%
 Irms: Based on temperature decrease 40°C
 Operating temperature range: -40°C ~ +125°C



What is ESR?

Inductors have resistance from the wire used to make the coil. This resistance is called the equivalent series resistance, or ESR. The ESR is often used to calculate resistive losses in inductors. It plays an important role in designing a power efficient inductive choke. The ESR of an inductor is made up of two elements: DC resistance and frequency-dependent resistance. The DC resistance can be calculated using Ohm's law. An inductor's ESR is particularly important in applications with low duty-cycle, high-frequency current pulses.

What is DCR?

Inductors allow DC (direct current) signals to pass through while blocking all high-frequency AC (alternating current) signals. Inductor DCR (DC resistance) is the amount of resistance an inductor presents for signals with frequencies of or near 0 Hz. The DCR is the resistance component of the coil of wire. It is important to consider the acceptable DCR of the inductor according to your application. Inductors with high DCR will have high losses which is bad for circuit efficiency. So, it is always better to select an inductor with lower DCR value when possible.

- In a DC circuit, an inductor appears as a short circuit with very little resistance.
- In an AC circuit, an inductor acts like a resistor that's value depends on the frequency of the AC source.

Current Ratings for Inductors

The current rating for the inductor, either chip inductor or power inductor, may specify either a saturation current (I_{sat}), rms current (I_{rms}), or DC current (I_{DC}) current.

The I_{rms} rating is a measurement derived from heat rise and reliability due to average inductor current while the I_{sat} rating is a performance indicator related to the instantaneous inductor current.

The I_{sat} is lower than I_{rms} for some inductors. This means that before the component temperature reaches its performance limit, the core will saturate. In this instance, the I_{sat} may be specified as the limiting factor. The more common occurrence is where the I_{sat} is higher than I_{rms} , the I_{rms} would be specified and the temperature rise above ambient.

For a standard ECS Inc. International inductor, we determine I_{rms} current rating.



The root means square (Irms) current rating is an indirect measure of inductor temperature rise to be expected from a given amount of power dissipation over 25°C ambient. This rating represents two factors: how much power dissipation is caused by an inductor current and how much temperature rise is a result of that power dissipation.

The Irms rating is not intended to capture all possible forms of power loss due to application conditions, only temperature. Because of this, the limitation is generally the temperature rating of the insulating materials in the inductor. Therefore, the Irms rating is a measure of how much current may be allowed in the inductor to ensure safe and reliable operation without heat damage to the inductor. Calculating the Irms current rating can be done by determining the circuit's maximum current.

= I²R

Where:

R is the DCR of the wire winding

I is the average or DC value of the inductor current

Calculate the Power Dissipated by Inductors

To calculate the DC power dissipated by the inductor, use:

P_{dc} = I_{rms}² x DCR

To calculate the AC power dissipated by the inductor, use:

P_{ac} = I_{rms}² x ESR

Where:

P_{dc} is the DC current through the inductor

P_{ac} is the AC current through the inductor

DCR is the DC resistance of the inductor

I_{rms} is the current through the inductor

ESR is the equivalent series resistance of the inductor

To calculate the total power dissipated by the inductor, use:



$$P_{total} = P_{dc} + P_{ac}$$

$$P_{total} = (I_{dc}^2 \times DCR) + (I_{rms}^2 \times ESR)$$

Calculating Inductor Power Losses

Temperature, frequency, and the AC and DC currents can all impact inductor power loss. Calculating inductor power loss for a specific application may be complicated, but there are equations that can provide estimations.

To calculate inductor power loss, use:

$$P_{lossInductor} = P_{core} + P_{dcr} + P_{acr}$$

Calculate P_{core}

Measuring core loss and getting accurate, repeatable results can be tedious for a design engineer. Typically, the calculated core loss can be acquired from the inductor provider, otherwise a formula can be used to calculate core loss.

$$P_{core} (mW) = K_1 F^x B^y \times V_e$$

Where:

K_1 is the constant for core material

F is the frequency (kHz)

B is the peak flux density (kGauss)

x is the frequency exponent

y is the flux density exponent

V_e is the effective core volume (cm³)

Calculate P_{dcr}

An inductor's DCR is the opposition to current flow through the inductor coil ($P=Core$). Because of this opposition to current you will have current losses in the coil. This is the measure of P_{dcr} . The wire loss caused by P_{dcr} is the easiest component to calculate.

$$P_{dcr} (W) = I_{rms}^2 \times DCR$$

Where:



I_{rms} is the rms value of the peak current
DCR is the DC resistance of the inductor

Calculate P_{acr}

The wire loss caused by AC resistance can be difficult to calculate because values like the AC winding resistance may not be readily available from vendors.

$$P_{acr} (W) = I_{rms}^2 \times ACR$$

Where:

I_{rms} is the rms value of the peak-peak ripple current
ACR is the AC resistance of the inductor

For additional information on power inductors, please visit our [Introduction to Power Inductors](#) technical guide or watch our [Power Inductors Product Overview](#) video.

To see our full line of power inductors, [click here](#).

Please [contact us](#) if you need additional information or have a specific requirement in your application.

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