Whitepaper

Key Specifications, Ratings, and Applications of Industrial Inductors

Inductors play a critical role in most electronic designs

The industrial market is challenging for electronics. Industrial rated components need to have a wider operating temperature range, and they are expected to operate with a high level of reliability, without a lot of extra cost.

TAIYO YUDEN

www.t-yuden.com

How Inductors Work

Fundamentally, an inductor stores energy in a magnetic field. A core ferrous material in the device is magnetized by a magnetic field generated when current flows through it. That magnetic field then resists changes to the current flowing through it.
The inductor is "charged", or storing maximum energy in its magnetic field, when the current through it reaches a steady state. If the supply current is removed, this magnetic field will continue to supply current to the load, but it will decay to zero over time based on the amount of energy stored in the inductor.

The ideal inductor is a purely reactive component. At DC steady state, an ideal inductor has no resistance to current flowing through it, and therefore has no voltage drop across it. Inductors resist changes to current flowing through them, and this can be seen in the equivalent of Ohm's Law for inductors, where instead of current, we see change in current over time, di/dt.

$$v = L \frac{di}{dt}$$

Where,

v = Instantaneous voltage across the inductor

L = Inductance in Henrys

$\frac{di}{dt}$ = Instantaneous rate of current change (amps per second)

Figure 1: "Ohm's Law" for an inductor

Because inductors impede changes to current, the relevant factor to how they operate in a circuit is the frequency component of the current, not the DC component. Real world inductors, however, have parasitic resistance and capacitance that cause them to not be purely reactive ideal devices. Real inductors have a typical impedance versus signal frequency curve that looks like the figure below (for different inductance values):

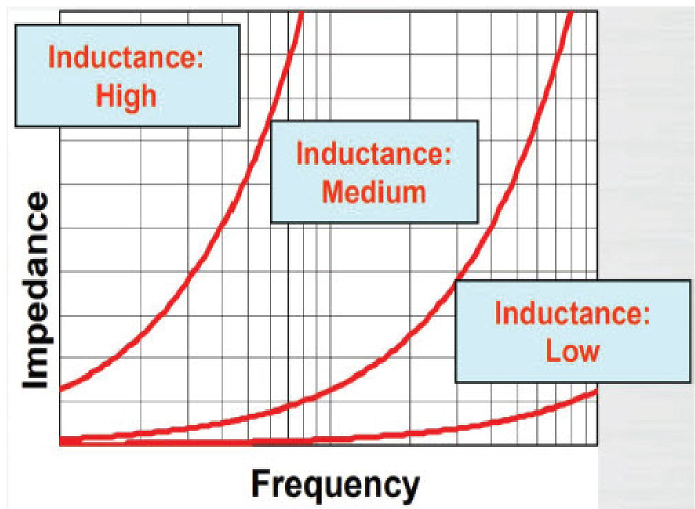


Figure 2: Typical impedance vs frequency cures for inductors

Key Specifications of Inductors

Inductance

The greater the inductance, the greater the tendency of the device to oppose changes to the current flowing through the device. The inductance of an inductor is dependent on the construction of the device - the geometry of the coils and the core materials used, primarily.

DCR - Direct Current Resistance

At steady-state DC current, an ideal inductor has no resistance. But real-world inductors have some impedance to DC current. DCR is responsible for most of the heat loss generated in an inductor. High current applications require both low DCR and high temperature ratings.

Impedance

The impedance of an inductor increases as the frequency of the applied voltage increases. Inductors are limited by their physical construction and materials so that there is a frequency (the self resonant frequency) at which impedance peaks and begins to drop as higher frequencies.

Saturation Current

Saturation occurs in a magnetic material at the point where increasing the magnetic field applied to it no longer increases its magnetization. The core material used in the inductor and the construction of the inductor create an upper limit to the energy they can store based on the current applied. That current is called the saturation current. When saturated, the inductance will fall and the current will increase dramatically. This is undesirable in almost all
applications, so selecting an inductor with a sufficiently high saturation current, or limiting the current applied to the inductor, is critical.

Rated Current

An inductor's rated current is the maximum current the device can safely withstand over the operating temperature range. Exceeding the rated current is likely to damage or destroy the inductor. This rating is based on the physical geometry of the wiring inside the inductor.

Self Resonant Frequency

The self resonant frequency (SRF) of an inductor is the frequency at which the inductance of the component resonates with its own parasitic capacitance. At the SRF, the inductor goes to a high impedance state. This can be useful to attenuate signals near that SRF. The SRF is an important parameter to know so as to avoid unintentionally operating near it.

Q Factor

The Q factor, or "quality factor," of an inductor is an indicator of how close to an ideal inductor it is at a specific frequency. A higher Q factor means the inductive reactance is high relative to the resistive impedance losses. Because this factor changes with frequency, Q factor characteristics of an inductor are usually provided as a chart of Q factor versus frequency.

Design Challenges

Real inductors are not ideal, presenting challenges when using them. Inductors are particularly susceptible to operating temperatures, self-heating, and unsafe failure modes.

Operating Temperatures

The soft ferrous or other materials used in the core of most inductors have characteristics that are usually very dependent on temperature. The inductance and DC resistance can both vary considerably with temperature.

Self-Heating

Operating and maximum allowable temperatures aren't just dependent on ambient temperatures. The design of the circuit and the usage of the inductor also play a significant role due to self-heating.

Physical Reliability

Inductors, like capacitors, are dependent on their physical structure and arrangement to function. This makes them more susceptible to shock and vibration damage than monolithic devices like resistors or silicon chips.

What Are Industrial Ratings?

Industrial rated components are intended for industrial equipment, and thus require a higher operating temperature range and increased reliability in rugged environments. Industrial equipment includes things like robotics, automated manufacturing lines, and plant infrastructure.

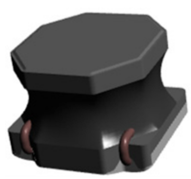
Figure 3: TAIYO YUDEN inductors are rated for various industrial applications.

For inductors, the challenges of industrial ratings are significant, due to their sensitivity to temperature and vibration, in particular. Commercial rated inductors may have temperature ratings up to 85° or 105°C, while industrial inductors have a maximum temperature rating of 125°C, typically. Inductor manufacturers, such as TAIYO YUDEN, need to take special care in material selection, design structure, and construction to make inductors that can pass qualifications for industrial ratings.

TAIYO YUDEN Industrial Inductors

TAIYO YUDEN, a leader in the development and production of electronic components, sells many inductors suitable for industrial use. Of particular interest are the newest series of industrial inductors – LBXH series, MCOIL™ LBEN and LSCN series.

LBXH Series



The LBXH series sleeveless power inductors offer many benefits for industrial applications. Sleeveless inductors are physically smaller because instead of a bulky sleeve containing and shielding the inductor, a molded resin does the same job better, with no gap to add losses.

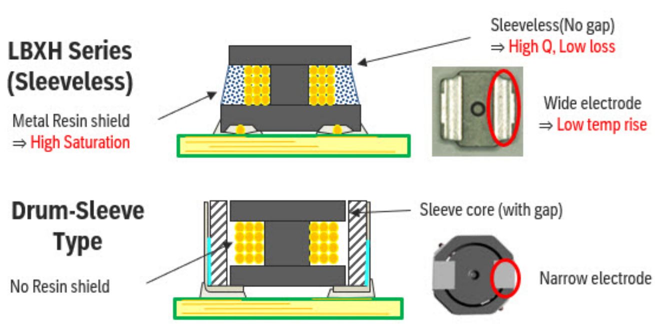


Figure 4: Sleeveless inductor cross section vs alternative

The LBXH series offers a number of other great features as well. Unlike other sleeveless inductors, the LBXH has side terminals that automated optical inspection (AOI) machines can see to confirm proper installation and soldering. Other sleeveless inductors only have small terminals beneath the component body, making them invisible to AOI equipment.

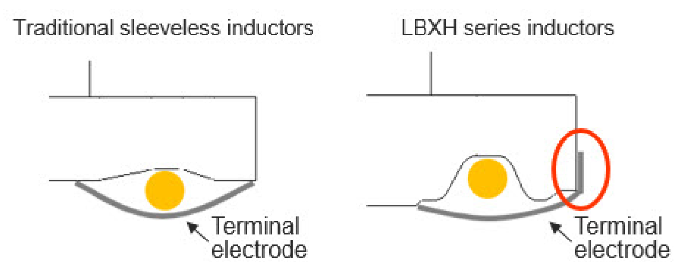
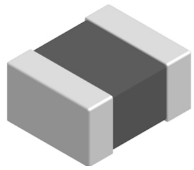


Figure 5: Traditional electrode structure vs LBXH series' side terminals

The LBXH series also has a higher saturation current, lower self-temperature rise, and higher Q factor. And while all of these characteristics are important for industrial inductors, one of the most important is stability over temperature. The LBXH series of industrial inductors have stable inductance across its wide temperature range of -40 to +125°C.

MCOIL™ LBEN Series



The LBEN series are surface mount power inductors with composite metal resin and five sided electrodes.

Because of the metal resin composite material, the LBEN series inductors are resistant to higher heat than standard inductors, and are thus higher reliability as well. Additionally, the advanced iron-based amorphous alloys coated with thermally stable oxides have increased the ESD performance as well, making the LBEN series highly reliable.

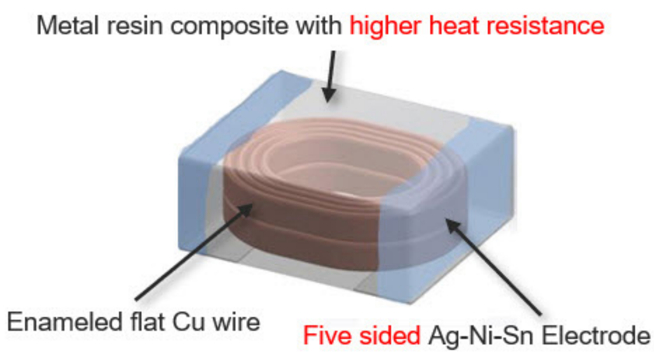
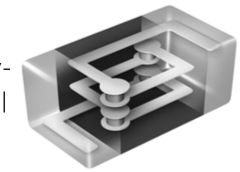


Figure 6: LBEN series construction

MCOIL™ LSCN Series



TAIYO YUDEN's LSCN series multilayer inductor with unique original metal material is the smallest industrial inductor in its class. It has a very high current rating for its size, with low magnetic flux. The LSCN series has tremendous inductance stability over both temperature and current, thanks to the unique original metal material used by TAIYO YUDEN.

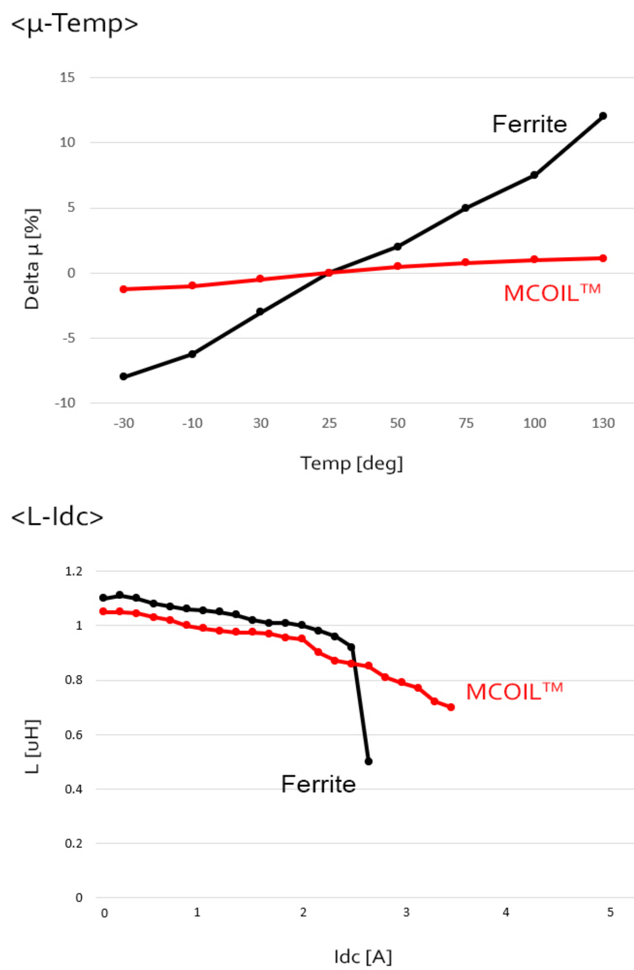


Figure 7 & 8: LSCN series inductance stability vs ferrite

TAIYO YUDEN Inductor Solutions

Industrial ratings present a challenge for inductors, but TAIYO YUDEN is up to the challenge. With a wide offering of industrial rated inductors, including the new series described here, TAIYO YUDEN is ready to enable all manner of industrial products.

TAIYO YUDEN (U.S.A.) INC.
2077 Gateway Place, Suite 350
San Jose, CA 95110
United States
www.t-yuden.com

Pub: May 2021

TAIYO YUDEN

Follow us on social media.