US patent n°4,936,961 - Demonstration for first inductor

Jason ALOYAU

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Course A coil is formed from a wire wound either in air or on a magnetic core. A driver traveled by a current i(t) creates a magnetic field, of flux $\boxed{\Phi}$, such than : $\boxed{\Phi = L * i(t)}$

The coefficient L is the inductance of the coil. Lenz-Faraday's law links the flow $\boxed{\Phi}$ to the f.é.m. u: $\boxed{u(t) = L * \frac{\mathrm{d}\Phi}{\mathrm{d}t}}$

The electrical characteristic of a coil is then given by : $\boxed{u(t) = L * \frac{\mathrm{d}i}{\mathrm{d}t}}$

The inductance L of a coil depends on the geometry, the number of turns N, the magnetic circuit Ex. : The inductance of a solenoid in air with 1 layer of N turns, of section $\boxed{S = \pi * r^2}$ and of length $\boxed{l \gg r}$: $\boxed{L = \mu_0 * \frac{S * N^2}{l}}$

$\boxed{\mu_0 = 4 * \pi * 10^{-7} H/m}$ is the permeability of the vacuum.
L in henry ; S in square meter ; l in meter ; r in meter

One of the useful characteristics of a winding produced with any magnetic core is the value $\boxed{L = \mu_0 * \mu_r * \frac{S * N^2 * S_m}{l_m}}$
$\boxed{\mu_r}$: the relative permeability of the magnetic circuit;
$\boxed{S_m, l_m}$: area and average length.

A coil stores energy in electromagnetic form when a current flows through it. The energy stored in a coil crossed by a current i at time t : $\boxed{E = \frac{1}{2} * L * i^2}$

The power supplied to the inductor : $\boxed{P = \frac{1}{2} * L * \frac{\mathrm{d}i^2(t)}{\mathrm{d}t}}$
It is difficult to quickly vary the current flowing in a coil, especially since the value of its inductance L will be large.

An ideal coil would have no loss of energy, but in reality, the conductor used for the winding also has a certain resistance which causes losses by Joule effect. The fact that the stored energy corresponds to a current flow gives the coil an inertia effect for the current. In particular, this current cannot be discontinuous. The use of a magnetic core makes it possible to reduce the number of turns for a given inductance, therefore the losses by Joule effect. However, there are also two types of losses in magnetic cores: 1. Losses by hysteresis proportional to the frequency; 2. The eddy current losses proportional to the square of the frequency. To account for these losses, a loss resistance R is introduced in series with L, or a resistance in parallel $\boxed{R_p}$.

Due to these physical properties, the coils are components that can hardly be miniaturized, and therefore very little used in on-board electronic circuits and even less in integrated circuits (ICs). Main characteristics of the inductors: The value of the inductor; Resistance of losses; The admissible current; Temperature coefficient, $\boxed{\alpha}$

Different categories: Air coils: Low inductance, Limited magnetic saturation, eg. used for high frequencies; Ferrite core coils: High inductance (for inductances from 0: 1 microH to 10 mH there are "miniature" coils resembling resistors.), Common frequency ranges 1 kHz to 100 kHz (but it is possible to extend to 1 GHz.) Close to saturation, the presence of the nucleus introduces non-linearities.

Calculations

We have the features :

$$\boxed{\begin{cases} N = 100 \\ r = 1,27 * 10^{-2} \\ S = r^2 = 1,6129 * 10^{-4} \\ l = 10 * 10^{-2} \\ \mu_0 = 4 * \pi * 10^{-7} \\ L = 2,03 * 10^{-5} \end{cases}}$$

N in turns ; r in meter ; S in meterˆ(2) ; l in meter ; L in henry ; $\mu_0$in henry per meter