US patent n°4,936,961 - Demonstration for transformer

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Course

The transformer transfers energy (in alternative form) from a source to a load, while modifying the value of the voltage. The tension can either be raised or lowered depending on the intended use. The change from one voltage level to another is done by the effect of a magnetic field.

Among the transformer applications, we note: 1. Electronics: (a) low voltage power supply; (b) impedance matching 2. Electrical engineering: (a) transformation of the voltage for the transport and distribution of electricity (b) low-voltage power supply (for example, halogen lamps) 3. Measurement: (a) transformers d current intensity (b) potential transformers. There are two main types of transformers, the battleship type and the column type. In the battleship type, a magnetic circuit with three branches is used, and the windings are around the central branch. In the column type, a two-column magnetic circuit is used.

The transformer consists of two (or more) windings coupled on a magnetic core.

The side of the source is called the primary. The side of the load is called the secondary. The flow (phi) is the mutual flow.

It should be noted that there is no electrical connection between the primary and the secondary. The entire coupling between the two windings is magnetic. When an AC voltage is applied to the source, this creates an AC flux in the magnetic core. According to Faraday's law, this flux creates electromotive forces in the coils. The induced electromotive force is proportional to the number of turns in the coil and to the rate of change of flux. According to the ratio of the number of turns between the primary and the secondary, the secondary supplies the load with a voltage difierent from that of the source.

Ideal transformer

We define an ideal transformer with the following characteristics: 1 - The resistance in the wires (primary and secondary) is zero. 2 - The magnetic core is perfect (mu_r = infinity, ro = 0). If we study the implications of these simplifications, we see that the reluctance of the core will be zero, and therefore there is no leakage. The flow is therefore completely contained inside the core. The magnetic coupling between primary and secondary is perfect; all the flow from primary goes to secondary. [A coupling parameter, k, is defined in the non-ideal case; for an ideal transformer, k = 1.]

We have : $\boxed{N_1 * I_1 - N_2 * I_2 = \Re * \phi = 0}$

$\boxed{N_1}$ is the number of turns of the primary coil of the transformer ; $\boxed{N_2}$ is the number of turns of the secondary coil of the transformer ; $\boxed{\Re}$ is the reluctance of the core ; $\boxed{\phi}$ is the magnetic flow in the core

The transformation ratio (a without unit) is defined as the ratio of the number of turns of the transformer. So :

$$\boxed{a = \frac{N_1}{N_2} = \frac{V_1}{V_2}}$$

$\boxed{V_1}$ is the voltage across the primary coil of the transformer in volt; $\boxed{V_2}$ is the voltage across the secondary coil of the transformer in volt

Hence we find :

$$\boxed{\frac{I_1}{I_2} = \frac{N_2}{N_1} = \frac{1}{a}}$$

$\boxed{I_1}$ is the current into the primary coil of the transformer in ampere; $\boxed{I_2}$ is the current into the secondary coil of the transformer in ampere;

Toroidal transformers

Toroidal transformers are inductors and transformers which use magnetic cores with a toroidal (ring or donut) shape. They are passive electronic components, consisting of a circular ring or donut shaped magnetic core of ferromagnetic material such as laminated iron, iron powder, or ferrite, around which wire is wound. though in the past, closed-core inductors and transformers often used cores with a square shape, the use of toroidal-shaped cores has increased greatly because of their superior electrical performance. The advantage of the toroidal shape is that, due to its symmetry, the amount of magnetic flux that escapes outside the core (leakage flux) is low, therefore it is more efficient and thus radiates less electromagnetic interference (EMI). Toroidal inductors and transformers are used in a wide range of electronic circuits: power supplies, inverters, and amplifiers, which in turn are used in the vast majority of electrical equipment: TVs, radios, computers, and audio systems.
In general, a toroidal inductor/transformer is more compact than other shaped cores because they are made of fewer materials and include a centering washer, nuts, and bolts resulting in up to a 50% lighter weight design. This is especially the case for power devices. Because the toroid is a closed-loop core it will have a

higher magnetic field and thus higher inductance and Q factor than an inductor of the same mass with a straight core (solenoid coils). This is because most of the magnetic field is contained within the core. By comparison, with an inductor with a straight core, the magnetic field emerging from one end of the core has a long path through air to enter the other end. In addition, because the windings are relatively short and wound in a closed magnetic field, a toroidal transformer will have a lower secondary impedance which will increase efficiency, electrical performance and reduce effects such as distortion and fringing. Due to the symmetry of a toroid, little magnetic flux escapes from the core (leakage flux). Thus a toroidal inductor/transformer, radiates less electromagnetic interference (EMI) to adjacent circuits and is an ideal choice for highly concentrated environments. Manufacturers have adopted toroidal coils in recent years to comply with increasingly strict international standards limiting the amount of electromagnetic field consumer electronics can produce.

<u>Calculations</u>

We have the features :

$$\boxed{\begin{cases} N_1 = 200 \\ N_2 = 600 \\ A = 9.10^{-6} \\ l_1 = 1.10^{-2} \\ l_2 = 1.10^{-2} \\ \mu_r = 1,26.10^{-4} \\ L_1 = 0,004536 \\ L_2 = 0,040824 \\ a = \frac{1}{3} \\ V_1 = 26 \\ V_2 = 78 \\ I_1 = 0,5 \\ I_2 = 0,167 \\ D_o = 39 \\ T_c = 3 \\ T_{D_o - D_i} = 7 \end{cases}}$$

$\boxed{\mu_r}$ is the relative permeability of the magnetic circuit in henry per meter ; $\boxed{D_o}$ is the outside diameter of the toroid core in millimeter ; $\boxed{T_c}$ is the thickness of the toroid core in millimeter ; $\boxed{T_{D_o-D_i}}$ is the space between the outside diameter and inside diameter in millimeter ; $\boxed{A}$ is the area of the toroid core in square meter $\boxed{L_1}$ is the inductance of the primary winding of the transformer in henry ; $\boxed{L_2}$ is the inductance of the secondary winding of the transformer in henry ; $\boxed{l_1}$ is the length of the primary winding of the transformer in meter ; $\boxed{l_2}$ is the length of the secondary winding of the transformer in meter