CALCULATION OF INDUCTION IN A RECTANGULAR CROSS-SECTION TOROID

Referring to Figure 1:

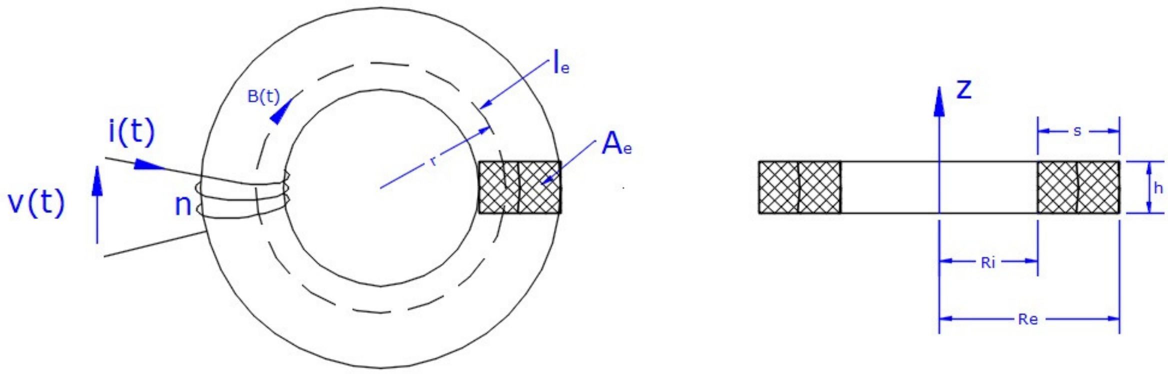

Figure 1: Wrapping of n turns around a toroid with a rectangular cross-section

Let's indicate the main equations that govern magnetic induction:

$\oint E \cdot dl = -\frac{d}{dt}\int B \cdot dA$ Faraday, Neumann, Lenz Law (FNL). 1.1

$\Phi = B \cdot A_e$ Relationship between magnetic flux and magnetic induction. 1.2

The calculation proceeds as follows. Suppose the voltage at the primary side v(t) is sinusoidal with a peak value V_p and frequency f:

$v(t) = V_p \cdot sen(2\pi f \cdot t)$ [V] 1.3

The peak value is related to the effective value Veff by the well-known formula:

$V_p = V_{eff} \cdot \sqrt{2}$ [V] 1.4

From the power in transit P [W] and the primary impedance Z_P [Ω], we obtain the effective voltage:

$V_{eff} = \sqrt{P \cdot Z_P}$ [V] 1.5

Integrating Faraday, Neumann, Lenz Law (1.1), we get:

$\int v(t)\, dt = -n \cdot \phi(t)$ 1.6

Substituting the equation for sinusoidal voltage (1.3) into (1.6), integrating, and rearranging, we obtain the flux value generated:

$\phi(t) = \frac{V_p}{2\pi f \cdot n} cos(2\pi f \cdot t)$ [T/m^2] 1.7

The maximum flux Φ is expressed by the coefficient multiplying the cosine term in (1.7). Therefore:

$\phi = \frac{V_p}{2\pi f \cdot n}$ [T/m^2] 1.8

The flux can, in turn, be substituted with (1.2), and the peak voltage with its effective value, as given in (1.5). Thus, we can derive the flux density B.

$$B = \frac{V_{eff}}{\sqrt{2}\pi f \cdot n \cdot A_e} \text{ [T]} \quad 1.9$$

Equation 1.9 allows us to calculate the flux density generated in the magnetic circuit when supplied with a sinusoidal voltage with an effective value of V_{eff}. The result will be in Tesla if the frequency f is expressed in Hz and the area A_e in m^2.

If, on the other hand, the frequency f is expressed in MHz and the area A_e in cm^2, then the result in mT (milliTesla) will be:

$$B = \frac{10 \cdot V_{eff}}{\sqrt{2}\pi f \cdot n \cdot A_e} \text{ [mT]} \quad \mathbf{1.10}$$

The relationship between Gauss and milliTesla (mT) is as follows:

$$1 \cdot G = 10 \cdot mT \quad 1.11$$

Manufacturer datasheets for ferrite cores always specify the maximum flux density B_{Max} as a function of temperature. Therefore, it is necessary for the flux density generated by the primary to always be lower than the maximum allowed.

$$B_{Max} > \frac{10 \cdot V_{eff}}{\sqrt{2}\pi f \cdot n \cdot A_e} \text{ [mT]} \quad 1.12$$

A safety margin of 20% is always necessary, so (1.12) becomes:

$$B_{Max} > \frac{12 \cdot V_{eff}}{\sqrt{2}\pi f \cdot n \cdot A_e} \text{ [mT]} \quad \mathbf{1.13}$$