

Method for

Calculation of the effective parameters of magnetic piece parts

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Committees responsible for this British Standard

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- Electronic Components Industry Federation
- Electronic Engineering Association
- Ministry of Defence
- National Supervising Inspectorate
- Telecommunication Engineering and Manufacturing Association (TEMA)

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National foreword

This British Standard has been prepared under the direction of the Electronic Components Standards Committee. It is identical with IEC Publication 205 “*Calculation of the effective parameters of magnetic piece parts*”, published in 1966 by the International Electrotechnical Commission (IEC), together with the supplementary matter given in Publication 205A issued in 1968 and Publication 205B issued in 1974 by the IEC. Amendments No. 1 (1976) and No. 2 (1981) to IEC 205 have also been incorporated.

For ease of production the French text associated with the formulae has been retained.

Terminology and conventions. The texts of the International Standard have been approved for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

Wherever there is a reference to IEC Publication 205 or its supplements, e.g., “Publication”, “Recommendation”, it should be interpreted as “British Standard”.

Cross-references. In the “List of symbols” reference is made to IEC 125 which is obsolescent.

The terms involving this reference are listed below as terms in IEC Publication 50(901) “*International Electrotechnical Vocabulary, Chapter 901: Magnetism*”, together with the term numbers of the related British Standard, BS 4727 “*Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms. Part 1. Terms common to power telecommunication and electronics. Group 07. Magnetism terminology*”.

Term	IEV reference	Term No. of BS 4727
(relative) amplitude permeability	901-03-04	3004
effective permeability	901-03-10	3010
(relative) initial permeability	901-03-05	3005

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 14, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Some notes on the use of effective parameters

When calculating the magnetic properties of cores on the basis of those of the material, use can be made of so-called effective parameters. For this method of calculation, the core is substituted by an ideal toroid such that a coil wound on that toroid would give exactly the same electrical performance as a coil with the same number of turns placed on the original core.

The magnetic properties and dimensional parameters of that substitute toroid are called the *effective parameters*. These are indicated by the suffix “e” added to the symbols for these properties.

These effective parameters are:

- the magnetic field strength H_e ;
- the induction B_e ;
- the effective permeability μ_e ;
- the magnetic path length l_e ;
- the cross-sectional area A_e ;
- the core volume V_e .

It is possible to calculate the effective parameters from the core dimensions and material properties when the following two assumptions are made:

- in every cross-section of the core the flux is the same (so there is no flux leakage);
- the flux is uniformly distributed over the cross section.

When using the effective parameters to calculate the hysteresis losses, the Rayleigh expression shall furthermore be valid:

$$\frac{B}{\mu_0} = (\mu_i + \nu \hat{H}) H \pm \frac{\nu}{2} (\hat{H}^2 - H^2) \quad (1).$$

The general magnetic circuit equations for a core of arbitrary geometry become simpler when the effective parameters are used, as follows:

$$\oint H \, dl = Ni \quad \text{becomes} \quad H_e l_e = Ni$$

$$\Phi = \int_A B \, dA \quad \text{becomes} \quad \Phi = B_e A_e$$

$$P_h = f \int_V dV \oint H \, dB \quad \text{becomes} \quad P_h = f V_e \oint H \, dB.$$

With the aid of $L = N \frac{\hat{\Phi}}{i}$ and $\frac{\tan \delta_h}{\mu_e} = \eta_B \hat{B}_e$ the following expressions can be derived, which can be used to calculate the effective parameters. For practical reasons, the dimensional parameters are normally expressed in millimetres, so that the appropriate power of 10 appears in the electro-magnetic equations.

¹⁾ The symbols used are explained on Pages 2 and 3.

$$C_1 = \Sigma \frac{l}{A} \quad (\text{See Note 1})$$

$$C_2 = \Sigma \frac{l}{A^2}$$

$$l_e = \frac{C_1^2}{C_2}$$

$$A_e = \frac{C_1}{C_2}$$

$$V_e = l_e A_e = \frac{C_1^3}{C_2^2}$$

$$\hat{H}_e = \frac{Ni}{l_e} 10^3$$

$$\hat{B}_e = \frac{u_{av} 10^6}{4 f A_e N}$$

$$\mu_e = \frac{C_1}{\Sigma \frac{l}{\mu_r A}}$$

$$\hat{B}_e = \frac{\hat{u} 10^6}{\omega A_e N} \quad (\text{See Note 2})$$

For cores and parts of cores with cross-sectional area which changes continuously along the magnetic path length, the summation of the above equations may be replaced by an integration.

¹⁾ Sometimes the permeance factor $c = \frac{\mu_0}{C_1} \cdot 10^{-3}$ (in henries) is used, mainly to calculate the effective permeability from the inductance factor.

²⁾ For sinusoidal voltage only.

With these effective parameters, the self inductance and the hysteresis losses can be calculated according to:

$$L = \frac{\mu_0 \mu_e N^2 A_e}{l_e} 10^{-3}$$

$$P_h = \frac{\eta_B \hat{u}^3}{2 \omega^2} \sqrt{\frac{\mu_0 \mu_e^3}{L^3 V_e}} 10^9.$$

The equations also hold true for a core with small air gap. This air gap is taken into account by the calculation of μ_e .

List of symbols

A	Cross-sectional area at a given part of the core (mm ²)
A_e	Effective cross-sectional area (mm ²)
B	Momentary value of flux density (T)
B_e	Momentary value of effective flux density (T)
$\hat{B}_e$	Peak value of effective induction (T)
C_1	Core constant (mm ⁻¹)
C_2	Core constant (mm ⁻³)
$\tan \delta_h$	Tangent of the loss angle due to hysteresis loss
f	Frequency [Hz (c/s)]
H	Momentary value of field strength (A/m)
$\hat{H}$	Peak value of field strength (A/m)
H_e	Momentary value of effective field strength (A/m)
$\hat{H}_e$	Peak value of effective field strength (A/m)
η_B	Hysteresis material constant (T ⁻¹)
i	Momentary value of current (A)
$\hat{i}$	Peak value of current (A)
l	Length of a part of the core with constant cross-sectional area (mm)
l_e	Effective magnetic length of the core (mm)
L	Self-inductance (H)
μ_0	Absolute permeability of vacuum, $4\pi \times 10^{-7}$ H/m