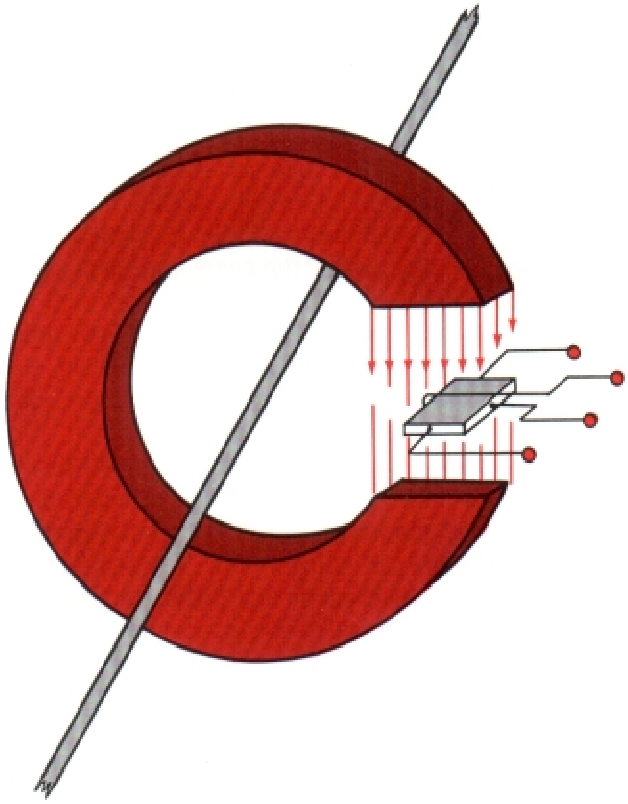
MAGNETICS

Division of Spang & Company

Technical Bulletin

HED -01

MAGNETIC CORES FOR HALL EFFECT DEVICES



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Introduction

Edwin H. Hall observed the Hall effect phenomenon at Johns Hopkins University in 1897. He monitored the current flowing from top to bottom in a thin rectangular strip of gold foil by measuring the voltages at the geometric center of the left edge and the right edge of the strip. When no magnetic field was present or when a magnetic field parallel to the strip was present, the voltages were identical; when a magnetic field perpendicular to the strip was present, there was a small voltage difference of the predicted sign and magnitude. The creation of the transverse electric field, which is perpendicular to both the magnetic field and the current flow, is called the Hall effect, or voltage. Reversing either the current or the field reverses the direction of the voltage.

In metals the effect is small, but in semiconductors, considerable Hall voltages can be developed and are being put to use in numerous Hall-effect devices. In copper, for instance, 0.024 mv per kilogauss at an 0.2-watt input can be obtained, but 110 mv per kilogauss at the same input is possible in semiconductors.

Hall effect devices are classified into two groups: (a) devices that use a constant magnetic field, and (b) those in which a signal or an oscillator produces at least part of the magnetic field.

Traditionally, engineers have not used Hall effect sensors because the cost of Hall cells and Hall hybrids and integrated circuits was much higher than opto or mechanical components. The cost of Hall components has dropped significantly, so cost is no longer a significant objection is most designs. Designers should consider using Hall sensors in many applications where mechanical or optical sensors have traditionally been used.

To monitor current flowing in a wire, the wire is wrapped around a ferromagnetic core, creating an electromagnet; the strength of the resulting magnetic field is used to measure the magnitude and direction of current flowing in the wire.

Hall-Effect Applications

The characteristics of a Hall generator make it suitable for detector elements in magnetometers, clip-on dc-ac ammeters, transducers (converting mechanical motion into electrical signals), magnetic-field variation meters, and wattmeters.

A comprehensive discussion on applications appears in a paper, “Applications of the Hall Effect” by W.E. Bulman of Ohio Semitronics Inc., Columbus, OH.

Core Permeability vs. Air Gap

In all cases, the effective permeability of a material will be a function of the size of the air gap introduced into the core and the initial permeability of the material one selects.

Permeability is defined as the ratio of magnetic flux density in gausses to magnetic field strength in oersteds:

$$\mu = \frac{B}{H}$$

If the magnetic circuit is not homogeneous (containing an air gap), the effective permeability is the permeability of a hypothetical homogeneous (ungapped) structure of the same shape, dimensions, and reluctance that would give the inductance equivalent to the gapped structure. By reviewing the classical inductance equation below, it is evident how the effective permeability comes into focus:

$$L = \frac{.4\pi N^2 \mu_e A_c \times 10^{-8}}{\ell_m}$$

L is in henries
A_c (core area) is in cm²
ℓ_m is the mean magnetic path length in cm

Therefore, how large the effective permeability is determines the inductance achieved from the core.

The next step is to determine effective permeability, μ_e:

$$\mu_e = \frac{\mu_i}{1 + \frac{(\ell_g)(\mu_i)}{\ell_m}}$$

μ_i = permeability of the material
ℓ_g = length of the gap in cm

Once the gap in a core becomes more than a few thousandths of an inch, the effective permeability is determined essentially by the air gap. The following examples bear this out.

(1) Consider a tape wound core made of 2-mil Supermalloy (80% Ni, 20% Fe) material, Magnetics Part No. 50026-2F with dimensions 1 .00 inches I.D. x 1.50 inches O.D. x .375 inches high. The initial permeability of this material (at B = 20 gauss, f = 100Hz) is 70,000. The effective permeability with a .070” gap (typical width to accommodate a Hall effect chip) is:

$$\mu_e = \frac{70{,}000}{1 + \frac{(.1778)(70{,}000)}{9.97}}$$

$= 56$

ℓ_g = .070"x2.54cm/"
= .1778cm
ℓ_m = 9.97 cm
A_c = .514 cm2

(2) Consider a similar size ferrite toroid core made of Magnetics F material and having the same size gap as above. The part number suggested is F-43806-TC with dimensions .750 inches x 1.500 inches x .250 inches. F material has a permeability of 3000.

$$\mu_e = \frac{3{,}000}{1 = \frac{(.1778)\ (3{,}000)}{8.30}}$$

$= 46$

ℓ_g = .070" X 2.54 cm/"
= .1778 cm
ℓ_m = 8.30 cm
A_c = .581 cm^2

As can be seen by the calculations, the effective permeabilities between example (1) and example (2) are very close even though in example (1) the initial permeablility is 20 times greater.

Designing a Hall Effect Core (Analytical Method)

1. Determine the flux operating extremes, based on:
   (a) $\Delta V / \Delta B$, **or**
   (b) maximum B sensitivity of the sensor
   (the above information from the semiconductor sensor data sheets)

2. Choose a core based on:
   (a) maximum or minimum dimensions requirements
   or
   (b) ID sized to fit large conductor, **and**
   (c) core cross-section dimensions
   (each should be at least twice the gap length to ensure a relatively homogeneous flux distribution bridging the gap).

3. Calculate the maximum required μ_e for the core:

$$\mu_e = \frac{B\ell_m}{.4\pi NI}$$

4. Calculate the minimum required gap length **in inches:**

$$\ell_g = \ell_m \left(\frac{1}{\mu_e} - \frac{1}{\mu_i}\right) (.3937)$$

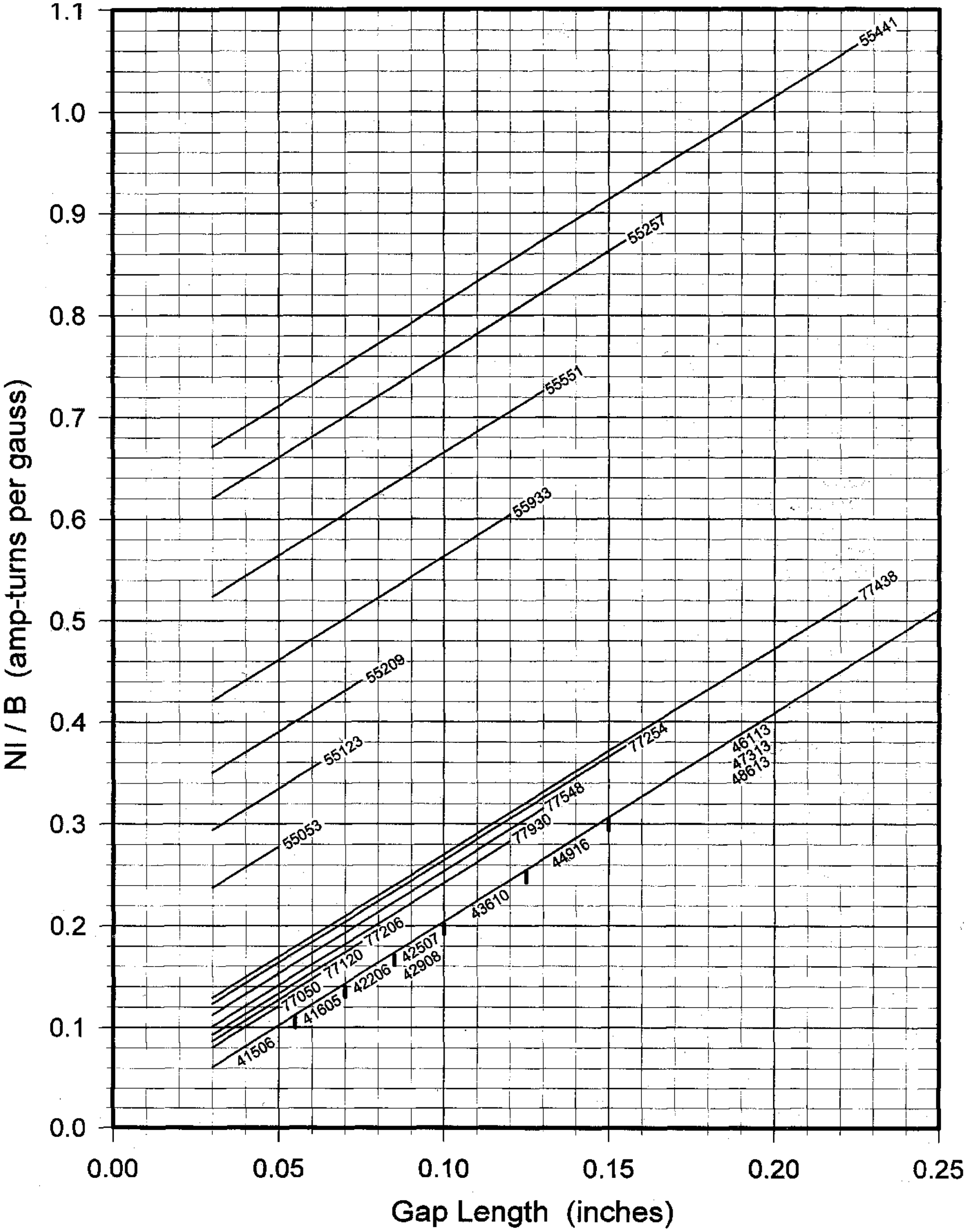
5. If the minimum required gap ***is greater than*** the sensor thickness, ensure that the cross-section dimensions (length and width) are at least *twice* the gap length. If not, choose a larger core. If the new core size has a different magnetic path length, recalculate for the required minimum gap.

Designing a Hall Effect Core (Graphical Method)

1. Calculate NI/B.
2. Reading the figure for (1) on the vertical axis of the Core Selector Chart, go horizontally to where it intersects with the diagonal line of the desired core type and size; go down vertically to read the gap length in inches.

On the diagonal lines, cores beginning with “5” are Molypermalloy powder (MPP) cores, those beginning with “7” are KOOL MU® types, and those starting with “4” are ferrite toroids.

Hall Effect Core Selector Chart



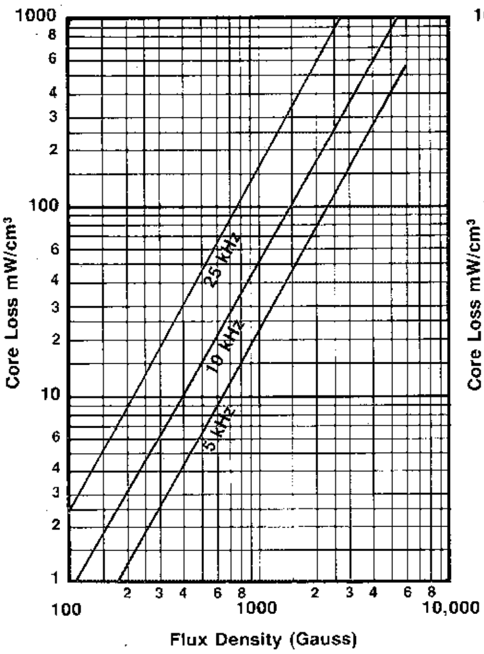
Variety of Cores Available

Magnetics makes a variety of cores manufactured from soft magnetic materials for use in Hall effect devices: Manganese-Zinc ferrites, Molypermalloy powder (MPP) cores, High Flux and Kool Mu® powder cores, and strip wound tape cores. Any of these can be provided gapped to accommodate the desired Hall chip. The core one chooses depends upon the characteristics of the core desired, cost, and temperature stability.

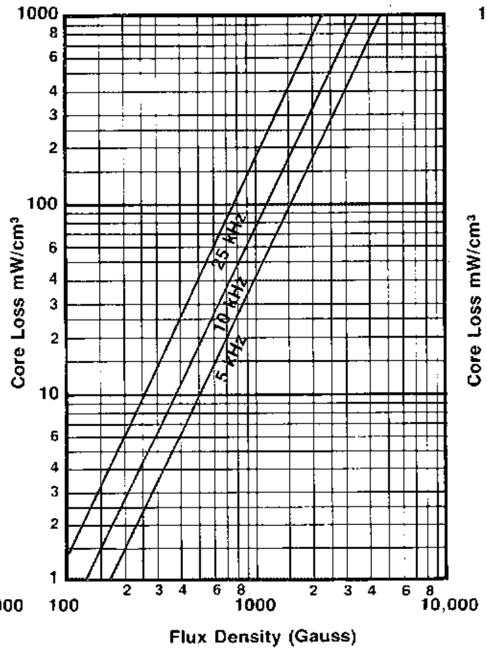
	Flux Density (Gauss)	Initial Permeability	Max. Operating Temperature	Literature Available
Ferrite Toroids				
R Material	5000	2300	200°C	Catalog FC-601
P Material	5000	2500	200°C	Catalog FC-601
F Material	4900	3000	200°C	Catalog FC-601
J Material	4300	5000	100°C	Catalog FC-601
MPP Powder Cores	7000	14-550	200°C	Catalog MPP-400
High Flux Powder Cores	15000	14-160	200°C	Catalog HFPC-01
Kool Mu® Powder Cores	10000	26-125	200°C	Catalog KMC-02
NiFe Tape Cores	7500-15000	To 100,000	200°C	Catalog TWC-400 Catalog MCC-100

Core Loss Curves
(Typical with .070" gap)

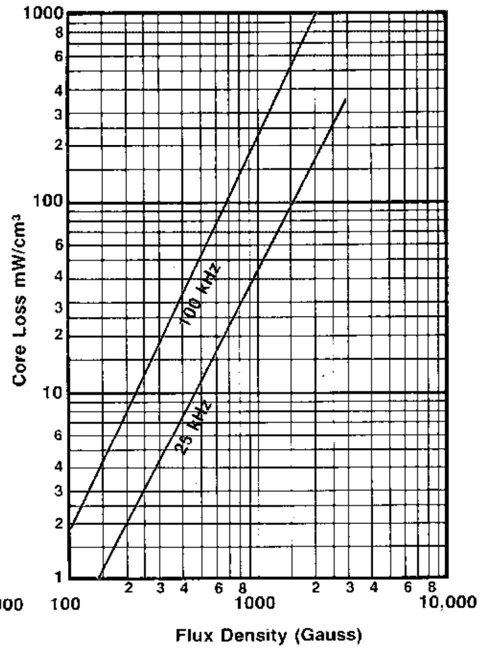
1 mil Permalloy 80 Tape Core



MPP & High Flux Powder Cores



Ferrite Cores



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KOOL MU® Powder Cores

Tape Wound Cores • Bobbin Cores

Ferrite Cores

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