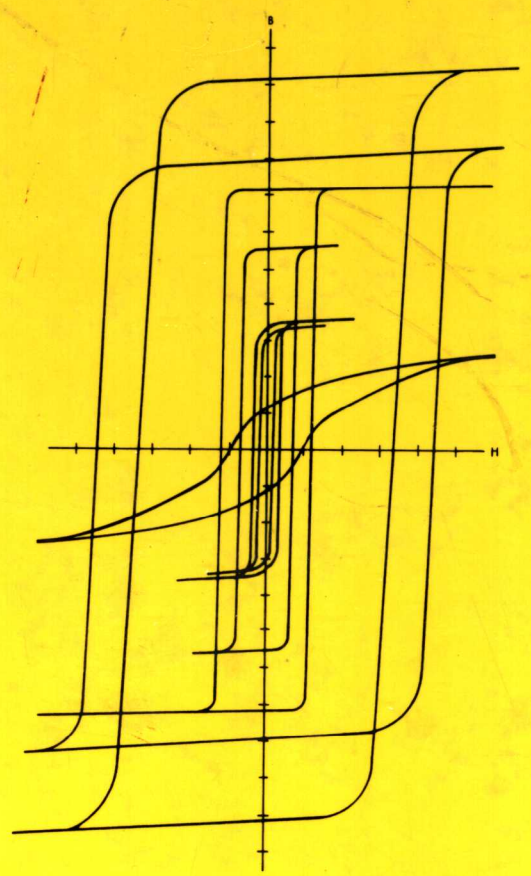
Magnetic Core Selection for Transformers and Inductors

A User's Guide to Practice and Specification

Second Edition



Colonel Wm. T. McLyman

about the second edition . . .

Written as a companion to the highly acclaimed *Transformer and Inductor Design Handbook, Second Edition* (Marcel Dekker, Inc.), this timely **new** edition of ***Magnetic Core Selection for Transformers and Inductors*** compiles the specifications of over 12,000 industrially available cores and brings them in line with standard units of measurements—simplifying the selection of core configurations for the design of magnetic components.

Maintaining the features that made the previous edition an invaluable resource, ***Magnetic Core Selection for Transformers and Inductors, Second Edition*** furnishes guidance on obtaining the **latest** data on ferrite cores, including all design parameters...manufacturers' core loss data curves and cross references for toroidal core retainers, and mounting brackets for C and E cores...useful transformer and inductor design procedures and equations presented in (cg) units...*revised* coverage of laminations, C cores, and Tape toroidal cores...information on the *latest* magnetic materials, such as Kool Mμ, Metglas, and Ferrites...an *updated and expanded* database of magnetic manufacturers...and more.

Presenting the material in a clear, easy-to-read tabular format, this ***Second Edition*** is a timesaving guide for electrical and electronics engineers and technicians, designers of magnetic circuits and electric components, and graduate-level students in these disciplines.

about the author . . .

COLONEL WM. T. MCLYMAN is the President of KG Magnetics, Inc., in San Marino, California, and a part-time lecturer and consultant in the field of magnetic component design. He also works full time for the Electric Power Systems Section of the Jet Propulsion Laboratory at the California Institute of Technology in Pasadena. Mr. McLyman has over 40 years of experience in power conversion and magnetic circuit design and holds 14 patents. The author of *Transformer and Inductor Design Handbook, Second Edition* (Marcel Dekker, Inc.), Mr. McLyman has written five published and widely distributed Technical Memorandums on the subject of magnetic materials and transformer design, as well as over 70 New Technology Reports, 50 of which have been published by NASA.

Printed in the United States of America ISBN: 0—8247—9841—4

MARCEL DEKKER, INC. NEW YORK • BASEL • HONG KONG

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Pasadena, California

MARCEL DEKKER, INC.

NEW YORK · BASEL · HONG KONG

Library of Congress Cataloging-in-Publication Data

McLyman, Colonel William T.,
Magnetic core selection for transformers and inductors: a user's guide to practice and specification / Colonel Wm. T. McLyman. – 2nd ed.
p. cm. – (Electrical engineering and electronics : 102)
Includes index.
ISBN 0-8247-9841-4 (alk. paper)
1. Magnetic cores. 2. Electronic transformers–Design and construction. 3. Electric inductors–Design and construction.
I. Title. II. Series.
TK7872.M25M36 1997
621.31'4–dc21 97-1909
CIP

The publisher offers discounts on this book when ordered in bulk quantities. For more information, write to Special Sales/Professional Marketing at the address below.

This book is printed on acid-free paper.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

Current printing (last digit):
10 9 8 7 6 5 4 3 2 1

PRINTED IN THE UNITED STATES OF AMERICA

FOREWORD

Magnetism first became apparent in the Ancient world as an attractive force that exists between two bodies such as lodestone or iron. Since that time, magnetism and later magnetic design, became viewed upon as an art or black magic. Colonel McLyman's first book entitled *Transformer and Inductor Design Handbook* (Marcel Dekker, Inc.) took a lot of the art and black magic out of magnetic design. That book took an easy to use step by step analytical approach that yielded accurate reliable magnetic component designs.

The present volume is an excellent supplement to the *Transformer and Inductor Design Handbook*. This new edition includes step by step design examples of transformers and inductors using powdered iron, molypermalloy, ferrites, cut cores, and so forth. It also has an up-to-date list of the manufacturers of all types of magnetic cores as well as coil forms, mounting hardware, magnet wire, and all the accessories necessary to manufacture magnetic components. This book also includes complete mechanical, electrical, and magnetic data on cut cores, strip wound cores, various powder cores, and ferrites supplied by all the core manufacturers. With this book, the magnetic designer literally has all the core manufacturers catalogs and data books at his finger tips. Many thanks, Colonel, for another valuable tool in the hands of the magnetic component designer.

Robert G. Noah
Magnetics, Division of Spang & Company
Butler, Pennsylvania

PREFACE

This book was written as a supplement to the *Transformer and Inductor Design Handbook: Second Edition, Revised and Expanded* (Volume 49). The idea was to bring the majority of the cores available in the industry in line with standard units of measurement to help the engineer pick the configuration best suited to a specific design.

The aforementioned handbook has new equations and procedures that simplify the design of magnetic components. The equations used in the handbook are in cgs units although magnetic core manufacturers supply data in mixed units and in no standard format. Most of the material in this book is in tabular form to assist the designer in making the trade-offs best suited for his particular application in a minimum amount of time. Approximately 20 core manufacturers are represented, with core types such as

1. Laminations
   (a) EI and EE
   (b) L and DU
   (c) UI
   (d) Three phase
2. C cores, 1, 2, 4, and 12 mil
   (a) EE cores, 4 and 12 mil
3. Tape toroidal core
   (a) Caseless, 1, 2, 4, and 12 mil
4. Ferrites
   (a) Toroids
   (b) EE, EI, and U
   (c) Pot cores
5. Powder cores

When the designer has established the area product A_p or the core geometry coefficient K_g, he can then look in this book for that particular core to obtain the following data:

1. Strip width (cm)
2. Buildup (cm)
3. Window width (cm)
4. Window length (cm)
5. Magnetic path length (cm)
6. Finished transformer height (cm)
7. Finished transformer width (cm)
8. Finished transformer length (cm)
9. Iron weight (gram)
10. Copper weight (gram)
11. Mean length turn (cm)
12. Iron area, A_c (cm^2)
13. Window area, W_a (cm^2)
14. Area product, A_p (cm^4)
15. Core geometry, K_g (cm^5)
16. Transformer surface area $(cm)^2$

Over 12,000 cores have been tabulated for the engineer. The engineer will find that some cores will have the same area product (A_p) or core geometry (K_g) coefficient but will have different

size configurations. With these data, the engineer can tell at a glance if that particular design or core configuration will work, or what changes will have to be made.

Possibly for the first time, many manufacturers' core-loss data curves have been organized with the same units for all core losses. The data were digitized right from the manufacturers' data sheets. Then the data were modified to put it in metric units—gauss to tesla and watts per pound to watts per kilogram. This data was then put into the computer to develop a new first-order approximation in the form

$$w = kf^m B^n,$$

where w is the calculated core loss density in watts/kilogram, f is the frequency in hertz, B is the flux density in tesla, and k, m, and n are coefficients derived using a three-dimensional least-square-fit law from the digitized data. These curves include silicon, nickel–iron, ferrites, powdered iron, and metglas. This book can now be used as a new tool to simplify and standardize the process of transformer design.

This new edition is an update using magnetic manufacturers latest catalogs. We also have broadened our database by adding more magnetic manufacturers. We have increased core data to include the latest magnetic materials such as Kool Mμ, Metglas, and Ferrite materials. We have also updated the laminations, C cores, tape toroidal cores, and ferrites.

This handbook provides the latest information on magnetic manufacturers. The data will assist the designer in making the trade-offs best suited to a particular application in a minimum amount of time. This new edition is a valuable tool for the engineer in magnetics design.

Colonel Wm. T. McLyman

ACKNOWLEDGMENTS

In gathering the material for this second edition and preparing it for publication, I have been fortunate in having the assistance and cooperation of a number of people and organizations and wish to express my gratitude to all of them. Too many have helped to mention them all, but I would like to list the following.

Jet Propulsion Laboratory
- Michael Hasbach
- Robert Detwiler
- Dr. John Klein
- Dr. Gene Wester

Magnetics
- Robert Noah
- Harry Savisky (Ret.)

Micrometals
- Jim Cox
- Walt Lewis
- Dale Nicol

Wilorco Inc.
- Kurt Willner

Sherwood Associates
- Ed Sherwood
- Erik Sherwood

and not forgetting . . .
- Charles (CT) Kleiner
- Robert Yahiro
- Laura Young
- Hung Ta

Thanks again!

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SYMBOLS

α	Regulation, %
A_c	Effective iron area, cm^2
A_p	Area product, $W_a A_c$, cm^4
AT	Ampere-turns
A_t	Surface area, cm^2
A_w	Wire area, cm^2
$A_{w(B)}$	Wire area bare, cm^2
AWG	American Wire Gauge
B_{ac}	Alternating current flux density, T
B_{dc}	Direct current flux density, T
B_m	Operating flux density, T
B_r	Residual flux density, T
B_s	Saturation flux density, T
cir-mil	Area of a circle whose diameter = 0.001 in.
E	Voltage
Eng	Energy, W s
η	Efficiency
f	Frequency, Hz
F	Fringing flux factor
H	Magnetizing force, amp-turns/cm
H	Magnetizing force, Oer
H_c	Magnetizing force to saturate
I	Current, A
I_{in}	Input current, A
I_m	Excitation current, A

I_o	Load current, A
I_p	Primary current, A
I_s	Secondary current, A
J	Current density, A/cm^2
K	Constant
K_e	Electrical coefficient
K_f	Waveform coefficient
K_g	Core geometry, cm^5
K_i	Gap loss coefficient
K_j	Current density coefficient
K_s	Surface area coefficient
K_u	Window utilization factor
K_v	Volume coefficient
K_w	Weight coefficient
L	Inductance, H
l_g	Gap length, cm
l_m	Magnetic path length, cm
l	Linear dimension, cm
MLT	Mean length turn, cm
MPL	Magnetic path length, cm
μ_Δ	Effective permeability
μ_m	Core material permeability
μ_o	Absolute permeability
μ_r	Relative permeability
n	Turns ratio
N	Turns

N_p	Primary turns
N_s	Secondary turns
P	Power, W
ϕ	Flux, Wb
P_{cu}	Copper loss, W
P_{fe}	Core loss, W
P_{in}	Input power, W
P_g	Gap loss, W
P_o	Output power, W
ψ	Heat flux density, W/cm^2
P_p	Primary loss, W
P_s	Secondary loss, W
P_Σ	Total loss (core and copper), W
P_t	Apparent power, W
R	Resistance, Ω
R_{cu}	Copper resistance, Ω
R_o	Load resistance, Ω
R_p	Primary resistance, Ω
R_s	Secondary resistance, Ω
R_t	Total resistance, Ω
S_1	Conductor area/wire area
S_2	Wound area/usable window area
S_3	Usable window area/window area
S_4	Usable window area/usable window area + insulation area
SF	Stacking factor
T	Flux density, T

V A	volt amps, watts
V_d	Diode voltage drop
V_{in}	Input voltage, V
V_o	Load voltage, V
V_p	Primary voltage, V
V_s	Secondary voltage, V
Vol	Volume, cm^3
W	watts
W_a	Window area, cm^2
W s	watt seconds
W_t	weight, grams
W_{tcu}	Copper weight, grams
W_{tfe}	Core weight, grams
ζ	Zeta resistance correction factor for temperature