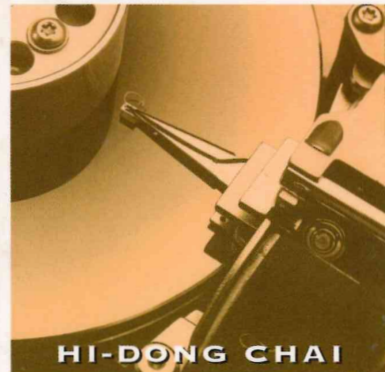
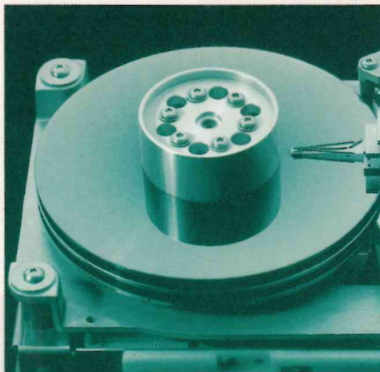
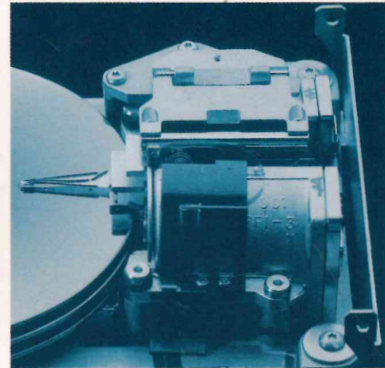
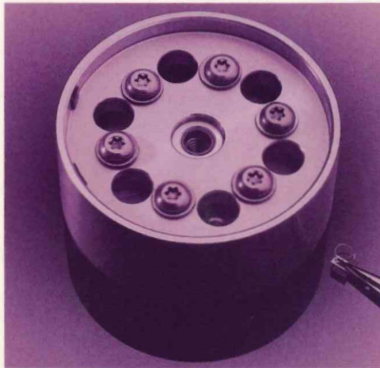


ELECTROMECHANICAL

MOTION DEVICES



HI-DONG CHAI

- ▶ HIGH-TECHNOLOGY MOTOR DESIGN: THEORY AND PRACTICAL TOOLS
- ▶ FUNDAMENTALS OF MAGNETIC FIELD THEORY
- ▶ VOICE COIL, STEP AND BRUSHLESS DC MOTORS
- ▶ COMPUTER SYSTEMS, PERIPHERALS, AND ROBOTICS APPLICATIONS

Electromechanical Motion Devices

Hi-Dong Chai
San Jose State University



Prentice Hall PTR
Upper Saddle River
New Jersey 07458
<http://www.phptr.com>



Library of Congress Cataloging-in-Publication Data

Chai, Hi-Dong.
Electromechanical motion devices / Hi-Dong Chai.
p. cm.
Includes bibliographical references and index.
ISBN 0-13-263419-8
1. Electromechanical devices. 2. Mechanical movements.
3. Motion. I. Title
TJ163.C53 1998
621.31'042—dc21 97-44407
CIP

Editorial Production: bookworks
Acquisitions Editor: Bernard M. Goodwin
Manufacturing Buyer: Alan Fischer
Cover Designer: Talar Agasyan
Cover Design Director: Jerry Votta



©1998 by Prentice Hall PTR
Prentice-Hall, Inc.
A Simon & Schuster Company
Upper Saddle River, NJ 07458

Prentice Hall books are widely used by corporations and government agencies for training, marketing, and resale.

The publisher offers discounts on this book when ordered in bulk quantities.
For more information, contact:

Corporate Sales Department
Phone: 800-382-3419
FAX: 201-236-7141
E-mail: corpsales@prenhall.com

or write:

Corporate Sales Department
Prentice Hall
One Lake Street
Upper Saddle River, New Jersey 07458

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-263419-8

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

5

Voice-Coil Motors

A voice-coil motor (vcm) is used in moving the read/write heads in hard disk drives or Direct Access Storage Devices (DASDs) which are used to store and retrieve digital information in computer systems. The name "voice-coil motor" was coined because the inventors got the idea for this motor from audio speakers. It consists of a movable *coil* in a gap and a *magnet* that provides a dc magnetic field in the gap. When a current flows in the coil, the coil experiences force (Lorentz force), resulting in motion. The direction of its motion is determined by the direction of the current flow in the coil. Since its function is to move the read/write heads, its motion is in a "stop and go" mode. The maximum distance that it travels is limited by the data band on the magnetic disk (in the range of 1 inch for 5.25-inch drives).

There are two types of voice-coil motors. One is called a linear vcm since it gives a motion in a straight line. The other is called a rotary vcm since its motion makes an arc. In this chapter we will use the linear vcm and develop necessary mathematical formulas or equations to gain insights into the operation of the vcm. We will study various magnetic structures used in the vcm design and develop tools necessary to analyze and design vcm magnetic structures. We will also address various aspects of the coil design which play an important role in the operation of a vcm. We also discuss the shorted turn which is a copper tubing placed around the magnetic circuit to reduce the effective coil inductance, so that the current builds up to its full value quickly. The last section is devoted to the design of a rotary vcm, which is playing a more and more important role in computers as the size of the disk drives becomes smaller.

Let us briefly survey the progress of the voice-coil motor used in the disk drive industry. Since the introduction of the first magnetic disk storage device, the IBM 350 in 1957, the advances in size reduction, storage capacity, and performance have been truly dramatic.

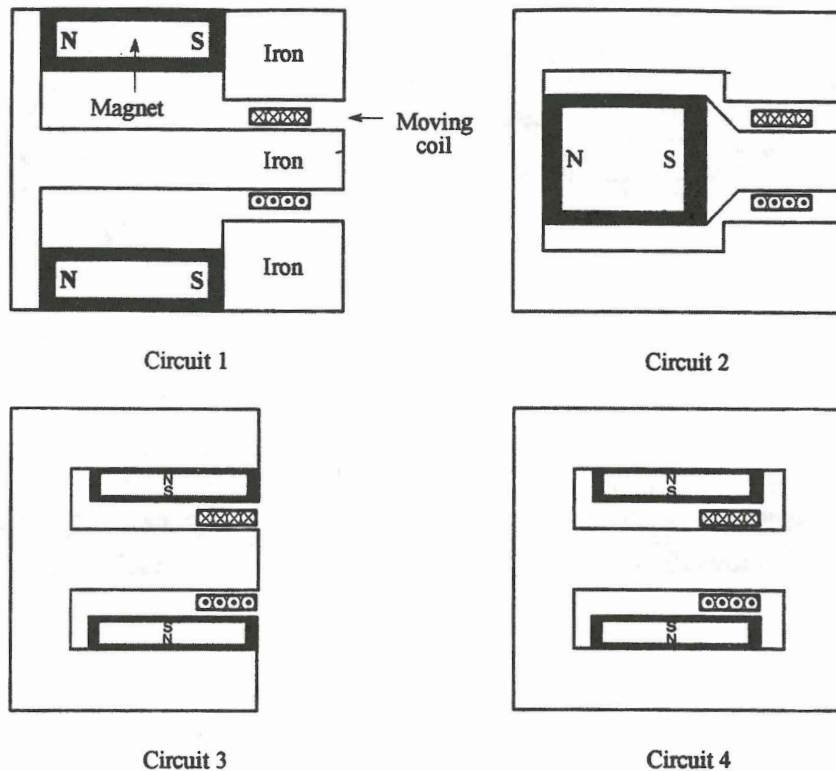


Figure 5-8 Lateral vcm cross section.

can easily shift the operating point. The ceramic magnets, on the other hand, have high coercivity (1.8–3.3 kOe) and a straight-line demagnetization curve with very low recoil permeability (1.05–1.15). Their drawback is low remanence (2.2–3.85 kGa). To provide high-gap flux density and at the same time avoid the demagnetization effect, old vcm's used circuits 1 and 2 shown in Figure 5-8. They were long and large by necessity, and the magnets were placed away from the gap, where the coil was placed.

With the introduction of high-energy product rare-earth cobalt magnets and especially neodymium magnets in the early 1980s, later vcm designs made use of circuits 3 and 4. In these designs, the magnets are thin and flat, and they are placed right at the gap. These designs are possible because the neodymium magnets have high remanence (10–13+ kGa), high coercivity (8–12 kOe), and a straight demagnetization curve with low recoil permeability (1.05).

Circuit 1 of Figure 5-8 is characterized by high leakage between the magnet and center core. The external leakage needs to be contained by shielding it to avoid interfering with the read/write process. Since the gap and the magnet are placed axially, this design tends to be long. The diameter of the center core has to be large enough to avoid saturation. Both the

ELECTROMECHANICAL

MOTION DEVICES

HI-DONG CHAI



HIGH-TECHNOLOGY MOTOR DESIGN—THE FIRST COMPLETE GUIDE! DIGITALLY-CONTROLLED MOTORS FOR COMPUTER SYSTEMS AND ROBOTICS

This is the first authoritative electromechanics text to focus primarily on building and implementing motors for computer systems, peripherals, and robotics. Hi-Dong Chai—recognized as a leading authority on magnetic actuator design—reviews the state-of-the-art in all aspects of contemporary small-scale motor design.

Electromechanical Motion Devices begins with the fundamentals every motor designer needs to know, including magnetic field theory. Next, the author introduces lumped-magnetic circuit fundamentals that are essential for the design and analysis of all magnetic devices.

- Includes extensive examples, exercises, practical tools, and techniques
- Applications include PCs, disk drives, printers, fax machines, and robotics
- Detailed coverage of voice coil motors, step motors, and brushless DC motors
- Materials for motion devices: coils, magnetic steel, and permanent magnets
- Transformers and dc machines—including the use of transformers in power supplies and as isolation devices

Understand the digitally-controlled precision motion devices used most often in the information industries: voice coil motors for positioning read/write heads in disk drives; step motors for discrete positioning applications; and brushless dc (BLDC) motors that are increasingly used in applications requiring a uniform speed in a well-controlled environment.

About the Author

HI-DONG CHAI is Professor of Electrical Engineering at San Jose State University. In 19 years at IBM, he became a recognized expert in the design and analysis of step motors, voice-coil motors, and print hammer actuators. He has 10 patents filed in the field, has published numerous papers, and formulated the gap permeance model that has been used extensively throughout the step motor community.

PRENTICE HALL
Upper Saddle River, NJ 07458
<http://www.phptr.com>

ISBN 0-13-263419-8

