

# THE MECHATRONICS HANDBOOK

Sleep Number Corp.  
EXHIBIT 2024

# The Electrical Engineering Handbook Series

*Series Editor*

**Richard C. Dorf**

University of California, Davis

## **Titles Included in the Series**

*The Avionics Handbook*, Cary R. Spitzer

*The Biomedical Engineering Handbook, 2nd Edition*, Joseph D. Bronzino

*The Circuits and Filters Handbook*, Wai-Kai Chen

*The Communications Handbook*, Jerry D. Gibson

*The Control Handbook*, William S. Levine

*The Digital Signal Processing Handbook*, Vijay K. Madisetti & Douglas Williams

*The Electrical Engineering Handbook, 2nd Edition*, Richard C. Dorf

*The Electric Power Engineering Handbook*, Leo L. Grigsby

*The Electronics Handbook*, Jerry C. Whitaker

*The Engineering Handbook*, Richard C. Dorf

*The Handbook of Formulas and Tables for Signal Processing*, Alexander D. Poularikas

*The Industrial Electronics Handbook*, J. David Irwin

*The Measurement, Instrumentation, and Sensors Handbook*, John G. Webster

*The Mechanical Systems Design Handbook*, Osita D.I. Nwokah and Yidirim Hurmuzlu

*The RF and Microwave Handbook*, Mike Golio

*The Mobile Communications Handbook, 2nd Edition*, Jerry D. Gibson

*The Ocean Engineering Handbook*, Ferial El-Hawary

*The Technology Management Handbook*, Richard C. Dorf

*The Transforms and Applications Handbook, 2nd Edition*, Alexander D. Poularikas

*The VLSI Handbook*, Wai-Kai Chen

*The Mechatronics Handbook*, Robert H. Bishop

*The Computer Engineering Handbook*, Vojin G. Oklobdzija

## **Forthcoming Titles**

*The Circuits and Filters Handbook, 2nd Edition*, Wai-Kai Chen

*The Handbook of Ad hoc Wireless Networks*, Mohammad Ilyas

*The Handbook of Optical Communication Networks*, Mohammad Ilyas

*The Handbook of Nanoscience, Engineering, and Technology*, William A. Goddard,

Donald W. Brenner, Sergey E. Lyshevski, and Gerald J. Iafrate

*The Communications Handbook, 2nd Edition*, Jerry Gibson

Sleep Number Corp.  
EXHIBIT 2024

# THE MECHATRONICS HANDBOOK

---

Editor-in-Chief  
**Robert H. Bishop**  
*The University of Texas at Austin  
Austin, Texas*



**ISA—The Instrumentation, Systems,  
and Automation Society**



**CRC PRESS**

---

Boca Raton London New York Washington, D.C.

Sleep Number Corp.  
EXHIBIT 2024



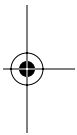
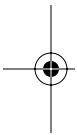
---

This reference text is published in cooperation with ISA Press, the publishing division of ISA–The Instrumentation, Systems, and Automation Society. ISA is an international, nonprofit, technical organization that fosters advancement in the theory, design, manufacture, and use of sensors, instruments, computers, and systems for measurement and control in a wide variety of applications. For more information, visit [www.isa.org](http://www.isa.org) or call (919) 549-8411.

---

**Library of Congress Cataloging-in-Publication Data**

Catalog record is available from the Library of Congress



This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the authors and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage or retrieval system, without prior permission in writing from the publisher.

All rights reserved. Authorization to photocopy items for internal or personal use, or the personal or internal use of specific clients, may be granted by CRC Press LLC, provided that \$1.50 per page photocopied is paid directly to Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923 USA The fee code for users of the Transactional Reporting Service is ISBN 0-8493-0066-5/02/\$0.00+\$1.50. The fee is subject to change without notice. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

The consent of CRC Press LLC does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from CRC Press LLC for such copying.

Direct all inquiries to CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431.

**Trademark Notice:** Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

**Visit the CRC Press Web site at [www.crcpress.com](http://www.crcpress.com)**

---

© 2002 by CRC Press LLC

No claim to original U.S. Government works  
International Standard Book Number 0-8493-0066-5  
Printed in the United States of America 1 2 3 4 5 6 7 8 9 0  
Printed on acid-free paper

Sleep Number Corp.  
EXHIBIT 2024



FIGURE 20.9 Assorts of solenoid actuators. (Courtesy of Shih Hsing Industrial Co., Ltd.)

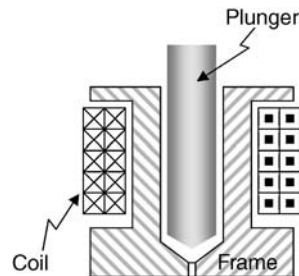


FIGURE 20.10 A typical solenoid.

### Solenoid Type Devices

Solenoids, see Fig. 20.9, is the simplest electromagnetic actuators that are used in linear as well as rotary actuations for valves, switches, and relays. As the name indicates, a solenoid consists of a stationary iron frame (stator), a coil (solenoid), and a ferromagnetic plunger (armature) in the center of the coil, see Fig. 20.10.

As the coil is energized, a magnetic field is induced inside the coil. The movable plunger moves to increase the flux linkage by closing the air gap between the plunger and the stationary frame. The magnetic force generated is approximately proportional to the square of the applied current  $i$  and is inverse proportional to the square of the air gap  $\delta$ , which is the stroke of the solenoid, i.e.,

$$F \propto \frac{i^2}{\delta^2} \quad (20.9)$$

As shown in Fig. 20.11, for strokes less than 0.060 in., the flat face plunger is recommended with a pull or push force three to five times greater than 60° plungers. For longer strokes up to 0.750 in., the 60° plunger offers the greatest advantage over the flat face plunger. When the coil is de-energized, the field decreases and the plunger will return to the original location either by the load itself or through a return spring.

All linear solenoids basically pull the plunger into the coil when energized. Push-type solenoids are implemented by extending the plunger through a hole in the back-stop, see Fig. 20.12. Therefore, when energized, the plunger is still pulled into the coil, but the extended producing a pushing motion from the back end of the solenoid. Return motion, upon de-energizing the coil, is provided by the load itself (i.e., the weight of the load) and/or by a return spring, which can be provided as an integral part of the solenoid assembly.

Sleep Number Corp.  
EXHIBIT 2024

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

## LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

## FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

## E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.