

- EXAMINES THE DIFFERENT TYPES OF BATTERIES AND THEIR CAPABILITIES
- COVERS SCIENCE, APPLICATIONS, RELIABILITY, AND SAFETY
- EXPLORES NEW AND FUTURE TECHNOLOGIES, INCLUDING LITHIUM ION AND NANOTECHNOLOGY



THE **TAB**<sup>TM</sup>



# BATTERY

AN IN-DEPTH  
GUIDE TO  
CONSTRUCTION,  
DESIGN, AND  
USE



# BOOK

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## MICHAEL ROOT

Foreword by Dr. Ralph J. Brodd

# **The TAB<sup>TM</sup> Battery Book**

## About the Author

**Michael Root, PhD**, is a battery electrochemist with over 20 years of battery research and development experience. He contributed to the development of battery technology for diverse applications like implantable medical devices and consumer electronics. His work may be found in patents, technical papers in peer-reviewed journals, and a book chapter on battery technology. Additionally, he wrote a number of articles for various general science publications.

# **The TAB<sup>TM</sup> Battery Book**

## **An In-Depth Guide to Construction, Design, and Use**

Michael Root



New York Chicago San Francisco Lisbon  
London Madrid Mexico City Milan New Delhi  
San Juan Seoul Singapore Sydney Toronto

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ISBN: 978-0-07-173991-7

MHID: 0-07-173991-2

The material in this eBook also appears in the print version of this title: ISBN: 978-0-07-173990-0, MHID: 0-07-173990-4.

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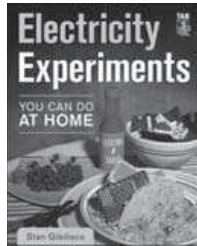
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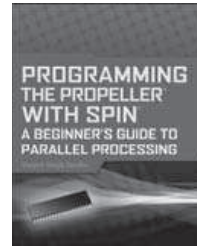
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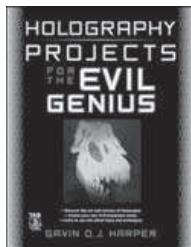
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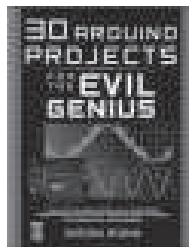
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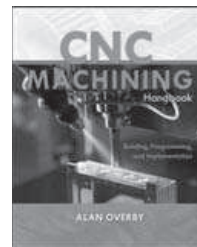
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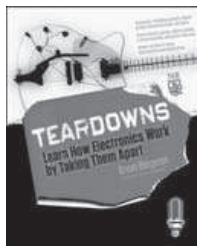
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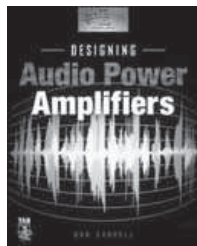
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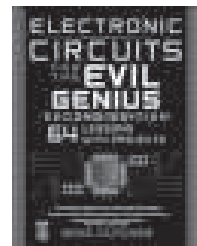
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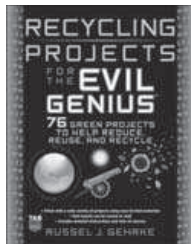
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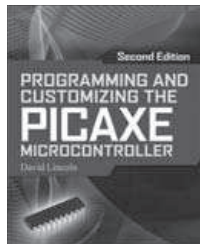
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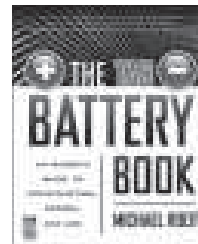
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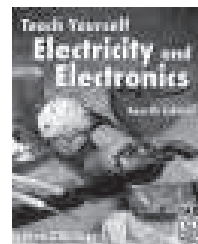
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# Foreword

*The TAB Battery Book* enables the reader to understand in simple layperson terms the complex operations that occur inside a battery in order to generate electrical power on demand. The author offers simple, easily understandable explanations of the complex chemical processes that occur inside a battery. The book is written to provide the typical reader with a working relationship with the batteries he or she uses in everyday life.

The author starts at the very beginning with fundamental descriptions of the Volta pile and continues with the Leclanché 1.5-volt primary battery for flashlights and early portable radios. He goes on to describe the rechargeable lead acid 2.0-volt battery that is now common to most automobile operations. Today, new high-energy systems find wide application, especially the lithium-ion battery with the very high energy density needed to power mobile phones and portable computers, and readers will find that these systems are well covered.

Batteries are capable of very efficient direct energy conversion and can deliver about 95 percent of the contained energy to useful work, compared to an internal combustion car engine, which converts in the range of 25 percent of the energy stored in gasoline to useful energy in propelling the car. An electrical generation plant that converts coal to electricity operates at about 40 percent efficiency.

Batteries are an integral component of our daily lives, whether in mobile phones, portable computers, starting your car engine, or powering the satellite that brings radio communication signals down to earth. The various battery systems are discussed and explained in language that everyone can easily understand.

The reader should find this book to be a valuable resource.

Ralph J. Brodd  
President of Broddarp of Nevada, Inc.

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# Introduction

The invention of the battery by Alessandro Volta over 200 years ago was one of those innovative leaps in technology that occur from time to time. Almost immediately after a letter from Volta describing his work was delivered to the Royal Society of London in 1800, the battery had a significant impact on science and technology.

Before the battery, electrical phenomena had to be studied using electrostatic sources. Electricity could be generated by friction (called triboelectric charging), such as rubbing together amber and wool, or harvested from natural sources, like lightning. The Leyden jar, a type of capacitor, was developed as a way to store electrical energy for later use.

The electrostatic energy produced from such sources could only be delivered in short bursts. This was not a practical way to deliver electrical energy. A more sustained source of electricity was needed.

The conversion of chemical energy to electrical energy accomplished what electrostatics could not. Assemble the right chemical substances in the right way and a controlled, sustained way of producing electricity can be available to almost anyone.

At first, batteries were used as a tool to study electricity and electrochemistry. The great English scientist Michael Faraday advanced our knowledge of electrochemical reactions. Faraday's mentor Humphry Davy discovered several new elements by electrochemical means using batteries as a power source.

It wasn't long before batteries were developed and commercialized to provide electricity for a number of different applications, like railway signals and telegraphs. As early as 1804, Charles Henry Wilkinson offered "different Galvanic Apparatus and Instruments" for sale on "moderate terms." A battery with fifty three-inch plates sold for five guineas. In the years before the invention of the electrical generator and construction of the electrical power distribution grid, battery installations provided electrical power. Some of the batteries developed in the nineteenth and early twentieth centuries we still use today—particularly lead acid, nickel-cadmium, and zinc-carbon batteries.

Many of the technologies we rely on today are enabled by batteries, including cellular phones, laptop computers, cars, and implantable pacemakers. The variety of battery types, sizes, shapes, and performance characteristics is vast. A complete description of any one of the batteries available today could fill a book on its own.



However, the intent here is to provide an overview of batteries from a number of different perspectives—how we use batteries, the historical foundations of today's battery technology, the scientific and engineering building blocks of batteries, different types of batteries (at least the more common ones), and some future directions of battery technologies. There should be something here for engineers, scientists, hobbyists, and students wanting to learn the basics of how batteries function and how to select the right battery for an application.

The idea for this book derives from a university professor I know who asked me to recommend a book to be used as supplemental course material for her course on electrochemical power sources. I had also been trying to think of ways to help provide information regarding battery technology to engineers who design batteries into their devices and those who procure batteries for the device design engineers. There are plenty of excellent reference books and specialized books aimed more at battery researchers and developers, but most of the more general battery books available are now out of print. So, *fiat liber*.

The book is divided into two sections: “Battery Basics” and “Battery Technologies.” The former discusses some of the general battery chemistry and engineering. The latter is a rundown of the more common battery technologies. A glossary and selected battery resources are provided at the end. The structure of those chapters devoted to the more technical aspects of battery science and engineering start with some basic information and go into more detail as the chapter progresses.

There are many books regarding battery science and technology that have been written since the early 1800s. A few of the more recent books providing information you may find useful include the outstanding reference book *Handbook of Batteries* edited by David Linden and Thomas B. Reddy, *Modern Batteries* by Colin A. Vincent and Bruno Scrosati, *Understanding Batteries* by R.M. Dell and D.A.J. Rand, and *Industrial Applications of Batteries* edited by M. Broussley and G. Pistoia. Also, Henry Schlesinger's *The Battery*, published during the writing of this book, gives an engaging account of the development of battery technology and the applications that use them.

This practical guide discusses battery chemistry and engineering, how batteries are used, and the history of batteries. You'll find out how different types of batteries work and how to select the right battery for any application. The book also examines the technological advances being used to develop batteries as robust energy sources for a wide variety of devices. Tap into the power of all kinds of batteries with help from this detailed resource. Coverage includes

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Battery engineering designs, including electrode, seal, and vent design. Battery performance, reliability, and safety. Primary battery technologies--aqueous and non-aqueous electrolytes, including alkaline and lithium.