



# Battery Operated Devices and Systems

From Portable Electronics to Industrial Products



Gianfranco Pistoia

TM911  
P679

# BATTERY OPERATED DEVICES AND SYSTEMS

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Industrial Products**

**G. Pistoia**



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## Preface

A number of handbooks are available to people working in the battery field, where batteries are the main subject and their applications are treated in much less detail. Conversely, there are no books dealing with the large spectrum of applications powered by batteries. In other words, although some books cover specific topics, for example portable devices, electric vehicles, energy storage, no books that aim to summarize all battery applications have thus far been published.

This book aims at bridging this gap, as many applications are reported in detail and others are mentioned, whereas less emphasis is put on batteries. However, basic characteristics of batteries and information on the latest developments are enclosed in a dedicated chapter. As is obvious, a 400-page single-author book cannot be as exhaustive as a multi-author large handbook. Nevertheless, the reader may find here, in addition to data on many applications, links to further literature through the many references that have been included. For researchers, teachers and graduate students interested in devices and systems drawing power from batteries, this book will be a useful information source.

In Chapter 1, all applications in the portable and industrial areas are introduced. Some market considerations follow, with details on the most important sectors, and a forecast to 2016 for portable devices is enclosed.

In Chapter 2, basic characteristics of all primary and secondary batteries used in the applications described are reviewed. The most recent trends, especially for the ubiquitous lithium ion batteries, are mentioned.

In Chapter 3, portable applications, for example mobile phones, notebooks, cameras, camcorders, several medical instruments, power tools, GPS receivers, are described with details on their electronic aspects. Particular emphasis is put on the devices' power consumption and management for their implications on battery life and device runtime. The basic features of some electronic components, for example microprocessors, voltage regulators and displays, are presented for a better understanding of their energy requirements. Battery management is also dealt with in detail, particularly in so far as the charging methods are concerned. The criteria of battery choice are stressed.

Chapter 4, on industrial applications, is the largest one, as it includes aerospace, telecommunications, emergency systems, load levelling, energy storage, different meters, data loggers, oil drilling, oceanography, meteorology, robotics, etc. The final part of this section is devoted to wireless connectivity, that is Wi-Fi, Bluetooth and Zigbee, exploited in many portable and industrial applications.

Chapter 5 deals with battery usage in vehicular applications. For their specific interest, these industrial applications are described in a section of their own. Full electric and hybrid vehicles are presented, and the role that the battery plays in the vehicle control systems is outlined.

Rome, March 2008  
Gianfranco Pistoia

## Chapter 1

# AREAS OF BATTERY APPLICATIONS

### 1.1. Introduction

This chapter aims at providing an overview of products and systems using batteries. Here, the term product indicates any device – small or large, portable or not – powered by a battery. The term system indicates a large installation, such as an energy storage plant to back up an electricity grid, or an extended sensor network.

Several criteria may be used to classify the countless applications of batteries reported in Table 1.1. In this book, three major categories have been considered: portable, industrial and traction/automotive. The first category is mainly represented by consumer applications but has to be extended to any application whose weight and volume allows portability. Therefore, even applications that a consumer rarely comes to know about, for example in the medical field, are enclosed in this category. Industrial applications encompass a wide spectrum, from robots to weather satellites, from oil drilling to telecommunications. Finally, traction and automotive applications include electric and hybrid electric cars, as well as their control systems. Strictly speaking, car-related applications should also be enclosed among the industrial ones. However, they are treated in a separate chapter because of their special interest: many people are willing to know more about these cars and their batteries in terms of performance, cost, reliability and development perspectives.

On the basis of these categories, Chapters 3, 4 and 5 will deal with applications typical of portable, industrial and traction/automotive batteries, respectively. However, in this chapter, some tables are anticipated: in Table 1.2, batteries are listed according to homogeneous groups of applications; in Table 1.3, applications or requirements in terms of current/power, duty cycle, dimensions, durability, etc., are reported together with the battery type/characteristic; in Table 1.4, the energy ranges of various battery-powered applications are indicated.

General characteristics of the main battery types are reported in Chapter 2. However, this book is more oriented to device (or system) description; more details on batteries can be found in the references listed at the end of that chapter.

Table 1.1. Applications using batteries (listed in alphabetical order).

---

Aerospace	Clockwise operated devices
Access control devices	Communications
Airborne control devices	diagnostic equipment
Aircraft	Communication – radio
Alarms – burglar	Communication
Alarm – fire	telephone systems
Alarm monitoring	Computer – portable
Alarm panels	Computer – home
Alarm – pollution	Computer laptop
Alarm refrigerator	Computer mainframe
Alarm water level	Computer peripherals
Alarm – seismic	Construction lasers
Alert devices	Control equipment
Animal ID readers	Converters/programmers
Animal tracking	Cordless telephones
Appliances – portable	Cordless toothbrushes
Audio video equipment	Counting
Automobile electronic systems	Industrial
Automotive accessories	Thermostatic
Automotive electronic memory	Timing
Automotive fuel systems	
Automotive	Data logging
locator for theft	Inventory
Automotive	Dental equipment – portable
security systems	Digital cameras
Avalanche rescue	Diving equipment
transmitters	
	EKG equipment
Backup power	Electric cash register
Ball pitching equipment	Electric door openers
Bar code scanners – portable	Electric fans
Bone healing aids	Electric fences
Buoy – oceanographic	Electric gates
	Electric locks
Cable TV	Electric meter transponders
Calculators	Electric trolling motors (fishing)
Calorimeters	Electric/electronic distributors
Camcorders	Electric/electronic scales
Cameras	Electric vehicles
Cargo tracking	Electronic counting systems
Chemical sensors	Electronic games
Cellular telephones	Electronic nerve stimulation units
Clocks	Elevator – escalators
Clocks – scientific	Emergency call boxes

Table 1.1. (Continued)

---

Emergency devices	Hearing aids
Emergency lighting	Hybrid electric vehicles
Emergency notification	
Entertainment	Identification
Musical instruments	Finger
Public address amps	Face
Stereo tuners	Hand
Tape recorders	Implantable medical devices
TV recorders	Industrial control equipment
VCRs	Industrial tools
Video cameras	Infrared equipment – portable
Environmental	Intelligent telephones
test equipment	
Exercise bikes and equipment	Laboratory analytical instruments
Exit lights	LAN power backup
	Lanterns
Facsimile machine	Lasers
Fiber-optic test equipment	Lifts
Fire alarm panels	Lights
Fire suppression systems	Camera, video, etc.
Fish finders	Highway safety
Flashlights	Maintenance
Flow meters (heat, gas and water)	Photographic
Fragrance dispensers	Railroad
Freeway call boxes	Underwater
	Load levelling
Game feeders and callers	
Garden equipment	Marine communications
Garage door openers	Marine instrumentation
Gas emergency cutoff systems	Marine depth finders
Gas meter transponders	Marine
Gas motor starting	underwater propulsion
Gas station elec. pump	Measuring and controlling devices
Geometrics	Measuring and dispensing pumps
Geophysical	Medical alert equipment
Seismic instruments	Medical beds
Surveying equipment	Medical CPR equipment
Golf carts	Medical crash carts
GPS equipment	Medical
	Bio-sensors
Hand-held computers	Blood oximeters
Hand-held test equipment	Cardiac monitors
Hand-held devices	Defibrillators

---

(Continued)

Table 1.1. (Continued)

---

Diagnostic equipment	Pagers
Dialysis machine	Parking lot tags
Drug dispensers	Parking meters – digital
Ear thermometers	PBX (private branch exchange) backup
Glucose meters	PDAs
Incubators	Personal organizers
Infusion pumps	Photovoltaic
Inhalators	Portable data entry terminals
Intravenous pumps	Portable lights
Life support equipment	Portable power line monitors
Sleep apnoea monitor	Portable measuring instruments
Telemetry equipment	Portable monitoring equipment
Therapy equipment	Portable public address systems
Wheelchairs	Portable transceivers
Memory backup devices	Portable VoIP
Metal detectors	Portable welding equipment
Meteorological instruments	Portable X-ray equipment
Meters	Power supplies
Electricity, gas, water	Power tools
Consumption	Printers – portable
Microwave	Probes
communications	Pulse power devices
Missile launch/tracking	Radar guns
Military electronics	Radio-controlled devices
Military fire control systems	Radio frequency ID tags
Military target range equipment	Railroad signalling
Mini-UPS	Real-time clocks
Modems	Refrigeration units
Monitors – portable	Rehabilitation devices
Motherboards	Remote level control
Motor starters	Remote site equipment
Muscle stimulator	Rescue transmitters
Musical instruments – electrical	Respirators
	Robots
Ocean current monitors	Satellites
Oceanographic equipment	Search and detection equipment
Office equipment	Scales and balance devices
portable/programm.	Security gates
Oil refinery backup	Security scanners
Ophthalmic instruments	Security systems
Optical instruments	Seismic measurements
Oxygen analysers	Sequence control equipment
Oxygen monitors	

Table 1.1. (Continued)

---

Shopping cart displays	Transponders
Smart cards	Transportation
Smoke alarms and detectors	Turner memories for VCRs
Solar energy storage	Two-way radios
Solar walklights	Ultrasound equipment
Spectrometers	Unmanned air systems
Speed measurement	Underwater gliders
Laser and radar	Uninterruptible power supplies (UPS)
Scoring systems	Utilities
Skydiving instruments	Vending machines
timing systems	Vehicle recovery systems
Stenography machines	Video cameras
Surgeon suits	VSAT backup power
Surveying instruments	Watches
Switching systems	Water treatment controls
backup power	Weather instrumentation
Taximeters	Well logging instrumentation
Telecommunications	Wheelchair and scooters
Timing devices	Wind energy storage
Toll road transceivers	Wireless products
Toys	Turnstiles
Electromechanical	Headsets
Programmable	Test equipment
Radio controlled	Wi-Fi and bluetooth
Riding	Word processing systems
Traffic delineators	Zigbee
Trailer tracking devices	
Transmitters	

---

## 1.2. Application Sectors and Market Considerations

The numerous applications listed in Tables 1.1 and 1.2 can be further grouped into the following sectors from a market standpoint [3].

### 1.2.1. Computing

This large and well-established sector includes portable computers, personal digital assistants (PDAs) and calculators. Portable computer batteries are typically lithium ion (Li-ion) and, less frequently, nickel metal hydride (Ni-MH). PDAs

Table 1.2. Applications using batteries (listed by homogeneous groups).

<b>Agricultural</b>	<b>Computing and Data Acquisition</b>
<ul style="list-style-type: none"> <li>• Livestock/game feeders</li> <li>• Livestock reproduction</li> </ul>	<ul style="list-style-type: none"> <li>• Computers &amp; peripheral equipment</li> <li>• Hand-held data gathering devices</li> <li>• Data loggers</li> </ul>
<b>Automotive</b>	<b>Control Equipment</b>
<ul style="list-style-type: none"> <li>• Electronic memory</li> <li>• Accessories</li> <li>• Fuel systems</li> <li>• Braking systems</li> <li>• Automatic crash notification</li> <li>• Tire pressure monitoring system</li> <li>• Electric bicycles/scooters</li> <li>• EV &amp; HEV</li> <li>• SLI (Starting, Lighting, Ignition)</li> <li>• Toll collection</li> </ul>	<ul style="list-style-type: none"> <li>• Thermostatic</li> <li>• Timing</li> <li>• Electro-mechanical systems</li> </ul>
<b>Back-up</b>	<b>Energy Generation, Transmission and Storage</b>
<ul style="list-style-type: none"> <li>• LAN</li> <li>• Memory</li> <li>• Uninterruptible power supplies (UPS)</li> <li>• PBX (Private Branch Exchange)</li> <li>• Mini-UPS</li> <li>• VSAT (Very Small Aperture [Satellite] Terminal)</li> </ul>	<ul style="list-style-type: none"> <li>• Solar generators</li> <li>• Wind generators</li> <li>• Load levelling</li> <li>• Electricity substations</li> <li>• Gas turbine control</li> </ul>
<b>Communications</b>	<b>Lighting</b>
<ul style="list-style-type: none"> <li>• Radio</li> <li>• Railroad signalling</li> <li>• Telephone systems</li> <li>• Global positioning equipment</li> <li>• Marine communications</li> <li>• Microwave</li> <li>• Portable transceivers</li> <li>• Two-way radios</li> <li>• Cordless &amp; cellular phones</li> <li>• Portable PA (Public Address) systems</li> <li>• Freeway call boxes</li> <li>• Automatic assistance system</li> </ul>	<ul style="list-style-type: none"> <li>• Emergency lighting</li> <li>• Exit lights</li> <li>• Hand-held lights</li> <li>• Highway safety</li> <li>• Photographic</li> <li>• Underwater</li> <li>• Lanterns</li> <li>• Solar walk lights</li> <li>• Traffic</li> <li>• Airport runway lighting</li> </ul>
	<b>Medical Applications</b>
	<ul style="list-style-type: none"> <li>• Electronic nerve stimulation units</li> <li>• Emergency devices</li> <li>• Heart defibrillators</li> <li>• Breathing-assistance equipment</li> <li>• Laboratory analytical instruments</li> <li>• Medical alert equipment</li> <li>• Medical beds</li> <li>• Medical CPR (Cardio-pulmonary Resuscitation) equipment</li> <li>• Medical crash carts</li> </ul>

Table 1.2. (Continued)

- Diagnostic equipment
- Dialysis machine
- Incubators
- Life support equipment
- Therapy equipment
- Wheelchairs
- Patient moving
- Telemetry equipment
- Infusion pumps
- Optic instruments
- Portable X-ray machines
- Cardiac monitors
- Dental equipment

**Military**

- Aerospace
- Aircraft instruments
- Missile launching/tracking
- Fire control systems
- Target range equipment
- Gunnery control

**Miscellaneous**

- Freon leak detectors
- End of train signalling
- Railroad track hot boxes
- Invisible fences
- Bowling alley lane cleaner
- DC power lifts
- Floor scrubbers
- Portable welders
- Industrial torque wrenches
- Traffic counters
- Portable heaters
- Laser products
- Robotics
- Lawn & garden equipment
- Point of sale terminals
- Switching systems
- Elevators
- Power tools
- Vacuum cleaners

**Monitoring Equipment**

- Airborne instruments
- Seismic instrumentation & alarms
- Surveying equipment
- Pollution alarms
- Transmitters
- Tracking systems
- Meteorological instruments
- Fiber-optic test equipment
- Portable monitors
- Bar code portable readers
- Ocean current monitors
- Portable power line monitors
- Search & detection equipment
- Scales & balance devices
- Scientific instruments
- Oil drilling
- Speed measurement
- Water consumption meters
- Heat consumption meters
- Electricity consumption meters
- AMR (Automatic Meter Readers)
- Gas consumption meters
- Gas flow meters

**Recreation**

- Sporting goods
- Trolling motors
- Fish finders
- Electronic deep sea fishing reel
- Tennis ball thrower
- Hobby craft
- Toys

**Security Systems**

- Burglar alarms
- Fire alarms
- Alarm panels
- Monitoring alarms
- Electric fences & gates
- Metal detectors
- Access control devices
- Ride-on

(Continued)

Table 1.2. (Continued)

**Video Equipment**

- Televisions
- Camcorders
- Audio-visual devices
- Cameras and video lighting
- Cable television

Table 1.3. Applications, or requirements, and related battery types.

Application/Requirement	Battery Types or Characteristics
Low-power, low-cost consumer applications	Low-power primary and secondary cells. Leclanché, alkaline, Ni-Cd, Ni-MH, primary lithium
Power tools, cordless equipment	Ni-Cd, Ni-MH, Li-ion
Small devices, hearing aids, watches, calculators, memory back up, wireless peripherals	Primary button and coin cells, zinc-air, silver oxide, primary lithium
Medical implants, long life, low self discharge, high reliability	Primary lithium, button and special cells
Automotive (starting, lighting and ignition (SLI))	Lead-acid
Automotive traction batteries	Lead-acid, Ni-MH, Li-ion, Na/NiCl <sub>2</sub>
Industrial traction batteries	Lead-acid, Ni-MH
Other traction batteries: robots, bicycles, scooters, wheelchairs, lawnmowers	Lead-acid, Nickel-Zinc, Li-ion, Ni-MH
Deep discharge, boats, caravans	Nickel-zinc, lead-acid, special construction
Standby power, UPS (trickle charged)	Lead-acid, Ni-Cd
Emergency power, long shelf life	Lithium, water-activated reserve batteries
Emergency power, stored electrolyte	Reserve batteries
Very high power, load levelling	Vanadium-redox flow batteries, Na/S, lead-acid, Ni-MH, Li-ion
Marine use, emergency power	Water-activated reserve batteries
High-voltage batteries	Multiple cells
High-capacity batteries, long discharge times	Multiple cells, special constructions, special chemistries
Low power, maximum energy density	Li-ion
Remote instrumentation	
Maximum power density	Primary lithium, Li-ion
Booster batteries, HEV applications	Ni-MH, Li-ion, Na/NiCl <sub>2</sub>

Table 1.3. (Continued)

Application/Requirement	Battery Types or Characteristics
Long shelf life, low self discharge	Primary lithium, special chemical additives
Long cycle life	Temperature controls, built-in battery management systems (BMS), recombinant systems, chemical additives
Satellites, aerospace applications	Ni-Cd, Nickel-H <sub>2</sub> , Li-ion, primary Li, Silver-zinc
High-energy density, lightweight	Zinc-air, primary lithium, Li-ion
Special shapes	Solid state, Li-ion polymer
Wide temperature range	Chemical additives, built in heaters, liquid cooling
Low maintenance	Sealed cells, recombinant chemistries
Inherently safe	Sealed cells, stored electrolyte, solid electrolyte, special chemistries
Robust	Special constructions
Missiles and munitions, safe storage, single use, robust, short one off discharge	High-temperature batteries
Torpedoes, short one off discharge	Water-activated batteries
Intelligent battery (communications between charger and battery)	Built in electronics to control charging and discharging
AC-powered devices	Built-in electronics (inverter) to provide AC power
Remote charging	Solar cells with deep discharge batteries
Short period power boost	Lithium, Ni-MH

Source: Adapted from Ref. [1]

typically use Li-ion batteries, and to a lesser extent Ni-MH or primary alkaline. Calculators may use alkaline, lithium or silver-zinc primary systems.

As with portable communications (see the next section), trends include an increasing convergence between cell phones and other portable products such as PDAs and cameras.

Driving forces and market developments include the following:

- Explosive growth has ended. Slow, but steady, sales until the next technology turning point.
- Tablet computers are becoming more important (mainly for commercial users). They are a viable alternative for many applications, and this could eventually grow from a niche market to a significant market sector.