



Premier Farnell



Guide To Battery Selection

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Farnell

Design with the best

Imagine a million tonnes of batteries!

Around 160,000 tonnes of consumer batteries, 190,000 tonnes of industrial batteries and 800,000 tonnes of vehicle batteries are sold in Europe every year. The most recent figures indicate Belgium, Sweden, Austria, Germany, Holland and France as having the most efficient systems in place to collect all types of used portable batteries.

The Battery Directive bans batteries containing more than 0.0005% of mercury and 0.002% of cadmium except in emergency and alarm systems, medical equipment and cordless power tools.

A quarter of all used batteries must be collected by 2012, rising to 45% in 2016, and at least half of them must be recycled. Many countries, including the UK, are nowhere near to these targets at present.

The directive calls for collection points to be established where consumers can hand in used batteries, including those from toys, computers, or mobile phones, and obliges shops to

collect batteries from consumers at no extra cost. It also says that all batteries must be removable, and that all producers of batteries must be registered.

The recycling targets are 75% by average weight for nickel-cadmium batteries, 65% for lead-acid batteries and 50% for others.

Other countries outside the EU have also introduced measures that affect batteries. Batteries are outside the scope of the EU-RoHS Directive because they are covered by the Batteries Directive, but they are included within the scope of "China RoHS" legislation which requires that they are marked with pollution control symbols. The US Batteries Act of 1996 restricts the use of mercury in batteries so that it is now permitted only in alkaline and silver oxide button cells. This Act also requires nickel - cadmium batteries to be specifically marked.

Battery selection

Introduction

Batteries were originally developed by Alessandro Volta in 1800 and have been the subject of research ever since. Today a wide range of battery types are available all of which have different characteristics that need to be understood in order to choose the most appropriate type. Certain batteries tend to be used for specific applications but price and size are often the main considerations. For example, zinc / carbon and alkali batteries are often used in torches as they are some of the cheapest types available and give reasonably long life. These same batteries could not be used in a mobile phone because they are not rechargeable. Hearing aids obviously need very small batteries with high capacity and so only certain types such as zinc / air can be used. Most electrical equipment is designed to function with a particular voltage and different battery types give different voltages. Therefore equipment designed to function with a 1.5 volt alkali battery will not be able to use a lithium ion battery that has a voltage, typically, of 3.7 volts. Batteries can be connected in series to give higher voltages as "battery packs" such as the well known standard 9 volt PP3 alkali battery which actually contains 6 individual cells connected in series.



Main battery types

Batteries can be classified as “primary” or “secondary” types. Primary batteries are fully charged when new but cannot be re-charged after they have discharged. Secondary batteries are “rechargeable” and include nickel / cadmium and lithium ion batteries. The table below lists some of the most commonly used battery types and their voltage:

Battery type	Cell voltage	Characteristics
Zinc - carbon	1.5 V	Low cost primary battery. One of the first batteries to be commercialised
Alkali	1.5 V	Primary battery with higher energy capacity than zinc carbon. Secondary types have been developed but are not widely available
Zinc air	~ 1.4 V	High capacity hearing aid battery that consumes air to generate electricity
Nickel / cadmium	1.2 V	Common rechargeable batteries. Suffers from the “memory effect” but widely used in power tools, emergency lighting, etc. Can be re-charged more times than lead acid.
Nickel - metal hydride	1.25 V	Developed as a cadmium-free substitute for nickel / cadmium. A suitable replacement for most conditions but characteristics are not identical
Lithium ion	3.7 V	Common rechargeable used in laptop PCs, mobile phones, etc.
Lithium manganese	3.0 V	Increasingly popular primary battery.
Lithium thionyl chloride	3.6 V	High storage capacity primary battery used as back-up power storage. Can be attached to PCBs
Lithium iron disulphide	1.5 V	High capacity, long life, primary battery which can be used in place of alkaline batteries
Lead acid	2.0 V	The first rechargeable batteries used in very large numbers in vehicles. Also used for back-up power storage such as in alarms. Can provide high current
Silver oxide	1.5 V	Small primary button cells that are a type of alkaline battery

This is not an exhaustive list of battery types and others are available, therefore choosing the optimum type for a new product design can be quite difficult.



Some of the variables that need to be considered are:

- Operating temperature - this varies depending on battery type. Operating some types at too high a temperature including the lithium batteries can be dangerous as explosions and fires have occurred. If the temperature is very low, the current available (discharge rate) from some types of battery can be much lower than at higher temperatures and this might restrict choice.
- Voltage - this can be an issue in some equipment although need not be if it is designed for the chosen battery type. Of course this means that it is not possible later to change to a type of battery with a very different voltage.
- Discharge rate (maximum current) - Some types of battery discharge at a higher rate than others so that more current can be drawn. Lead acid batteries are used in vehicles because they can give very high current for short periods whereas alkaline batteries are designed for long life and so are not intended to give large currents.
- Self-discharge - The rate of self-discharge should also be considered as this affects their shelf life. This occurs all of the time including when the battery is not being used and eventually results in the battery going flat. Some types have extremely low self-discharge rates such as most of the lithium battery types whereas some nickel metal hydride batteries can lose up to 4% of their capacity every day.
- Recharging - The number of times that rechargeable batteries can be charged and discharged depends on the type of battery. It also depends on whether the battery is "trickle charged" (on continuous charge to maintain full capacity such as alarm batteries, emergency lighting batteries and combustion-engine car batteries) or experiences full discharge before re-charging (such as batteries in an electric toothbrush or an electric car). Batteries usually last much longer when used on a trickle charge than with deep discharge although this can consume a lot more power providing continuous charging. The number of discharge / recharge cycles that a battery can provide without significant loss of performance depends on the type of battery, and there can be significant variations.

Some of these characteristics are summarised in the table below:

Battery type	Relative cost	Operating temperature range °C	Capacity *** Wh/kg	Self-discharge rate per month ****
Rechargeable cells				
Lead acid	Low	-65 to 80*	20 - 40	~5%
Nickel cadmium	Medium	-20 to 65	40 - 50	1 - 10%
Nickel metal hydride	Medium	-10 to 65	50 - 70	4 - 30%
Lithium ion	Expensive	-20 to 60	150	Loses ~ 0.1%
Primary cells				Storage life
Zinc carbon	Low	-10 to 50	60 - 100	2 years
Alkaline	Medium	-20 to 60**	~160 (but less with high current drain)	Up to 5 years
Lithium manganese	High	-40 to 70**	290	10 years
Lithium iron disulphide	High	-40 to 60	300	10 years
Lithium thionyl chloride	High	-10 to 65 (some can be used -50 to 150)	330 (some can be up to 700)	10 - 20 years
Zinc air	High	0 to 40	Up to 340	Unlimited in theory when sealed. Very high when exposed to air

Notes

* Note that this depends on the type of lead acid battery

** Varies depending on type

*** Working out how long a battery will last is much more complicated than looking at the storage capacity as this is also affected by the current that the battery will provide and its self-discharge rate. Some types of batteries go flat even without being used. Some, such as alkaline batteries, have limited current output which decreases with use. The equipment stops working when the available current drops below a minimum value.

**** This actually depends on the ambient temperature and is lower at low temperature.

Wh/kg is energy capacity per kg of battery. Figures here are from various sources and as technology improves some of the figures that can be achieved will increase.

Recharging

Each type of rechargeable battery needs a charger to cope with the specific voltage requirements and to prevent overcharging. This is particularly important for lithium ion batteries which can explode if over-charged. Lithium ion battery chargers are designed to control voltage but there should be additional control circuitry either inside the battery or as part of the equipment's circuitry.



Reliability issues

All types of rechargeable batteries have a finite life as they can only be charged and discharged a certain number of times. If this is considerably less than expected, it usually indicates that battery charging has not been carried out correctly as it is unusual for the battery to be defective.

Failures of lithium batteries do occasionally occur but in comparison with the huge numbers sold, this is extremely rare. Recently, dramatic failures of lithium ion batteries used in laptop computers were widely reported in the press. In this case, the manufacturer admitted that their batteries were defective. Failures of lithium camera batteries have also been reported in letters published in photographic magazines.

Failures can be dramatic because lithium is a very reactive metal producing flammable hydrogen gas on contact with water and it also burns readily in air. Lithium batteries are designed to prevent failures but these measures are not always foolproof and failures can occur if the batteries are used incorrectly. Lithium ion batteries for example do not normally contain elemental lithium metal but it is produced if the battery is overcharged or even if it is over-discharged. Overcharging and over-discharging is a common problem and can be dangerous but is avoided by use of appropriate control circuits. Over-heating and short-circuiting of some types of lithium battery can also lead to failures.

UK Batteries Regulations

The Government has introduced regulations relating to the collection, treatment and recycling of batteries in the UK. The regulations came into force on **5 May 2009**.

Anyone who places portable batteries / accumulators - or products containing portable batteries / accumulators - onto the **UK market** for the first time (which generally means that they have not bought them from another UK supplier), will be classified as a **battery producer**. This includes retailers and importers, as well as wholesalers who import portable batteries / accumulators to place on the UK market.

Previously, it was thought that all battery producers would have to pay to join a Battery Compliance Scheme. However, the Government made a distinction between large and small producers.

Producers who place **more than 1 tonne** of portable batteries onto the UK market each year, will have to pay for the collection, treatment, recycling and disposal of waste batteries, in proportion to their market share. They will do this by joining one of the seven approved Battery Compliance Schemes which will arrange for the collection, treatment and recycling of waste batteries for them. They will also register producers with the appropriate environment agency.

Producers who place **less than 1 tonne** of portable batteries onto the UK market each year will not have to pay for the collection and treatment of waste portable batteries but they still have to register themselves with their local environment agency.

All producers of portable batteries are obliged to **provide data** on the amount and weight of batteries they have placed on the market since 5 May 2009.

Retailers selling more than 32 kg of portable batteries / accumulators each year, will also have a responsibility to take them back in-store from 1 February 2010.