

## What's the best battery?

Battery novices often brag about miracle batteries that offer very high energy densities, deliver 1000 charge/discharge cycles and are paper-thin. These attributes are indeed achievable but not on one and the same battery pack.

A certain battery may be designed for small size and long runtime but has a limited cycle life. Another pack may be built for durability and is big and bulky. A third may have high energy density and long durability but is made for a special application and is too expensive for the average consumer. A lithium-based battery can be designed for maximum energy density but its safety would be compromised.

Battery manufacturers are aware of customer needs and offer packs that best suit the application. The mobile phone industry is a good example of this clever adaptation. Here, small size and high energy density reign in favor of longevity. Short service life is not an issue because a device is often replaced before the battery is worn out.

Below is a summary of the strength and limitations of today's popular battery systems. Although energy density is paramount, other important attributes are service life, load characteristics, maintenance requirements, self-discharge costs and safety. Nickel-cadmium is the first rechargeable battery in small format and forms a standard against which other chemistries are commonly compared. The trend is towards lithium-based systems.

Nickel-cadmium - mature but has moderate energy density. Nickel-cadmium is used where long life, high discharge rate and extended temperature range is important. Main applications are two-way radios, biomedical equipment and power tools. Nickel-cadmium contains toxic metals.

Nickel-metal-hydrate - has a higher energy density compared to nickel-cadmium at the expense of reduced cycle life. There are no toxic metals. Applications include mobile phones and laptop computers. NiMH is viewed as steppingstone to lithium-based systems.

**Lead-Acid:** Most economical for larger power applications where weight is of little concern. Lead-acid is the preferred choice for hospital equipment, wheelchairs, emergency lighting and UPS systems. Lead acid is inexpensive and rugged. It serves a unique niche that would be hard to replace with other systems.

**Lithium-ion** - fastest growing battery system; offers high-energy density and

low weight. Protection circuit is needed to limit voltage and current for safety reasons. Applications include notebook computers and cell phones. High current versions are available for power tools and medical devices.

Table 1 summarizes the characteristics of the common batteries. The figures are based on average ratings at time of publication. Lithium-ion is divided into three versions: The traditional cobalt that is commonly used in cell phones, cameras and laptops; the manganese (spinel) that power high-end power tools and the new phosphate that competes head-on with spinel. Lithium-ion polymer is not listed as a separate system. Its unique construction performs in a same way to cobalt-based lithium-ion.

Table 1: Characteristics of common only used rechargeable batteries.

- 1) Internal resistance of a battery pack varies with m/Ah rating, wiring and number of cells. Protection circuit of lithium-ion adds about 100mW.
- 2) Based on 18650 cell size. Cell size and design determines internal resistance. Larger cells can have an impedance of <15mOhms,
- 3) Cycle life is based on battery receiving regular maintenance. Failing to apply periodic full discharge cycles may reduce the cycle life by a factor of three.
- 4) Cycle life is based on the depth of discharge. Shallow discharges provide more cycles than deep discharges.
- 5) The self-discharge is highest immediately after charge, and then tapers off. The capacity loss of nickel-cadmium is 10% in the first 24h, then declines to about 10% every 30 days thereafter. High temperature increases self-discharge.
- 6) Internal protection circuits typically consume 3% of the stored energy per month.
- 7) The traditional nominal voltage is 1.25V; 1.2V is more commonly used to harmonize with lithium-ion (3 in series = 3.6V).
- 8) Lithium-ion is often rated higher than the nominal 3.6V. Based on average voltage under load.
- 9) Capable of high current pulses; needs time to recuperate.
- 10) Applies to discharge only; charge temperature range is more confined. Delivers lower capacity at lower temperatures.
- 11) Maintenance may be in the form of 'equalizing' or 'topping' charge to prevent sulphation.

In subsequent columns I will describe the strength and limitation of chemistry in more detail. We will examine charging techniques and explore methods to get the most of these batteries.

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