# Electrical Supply, Batteries (6-POWER MANAGEMENT)

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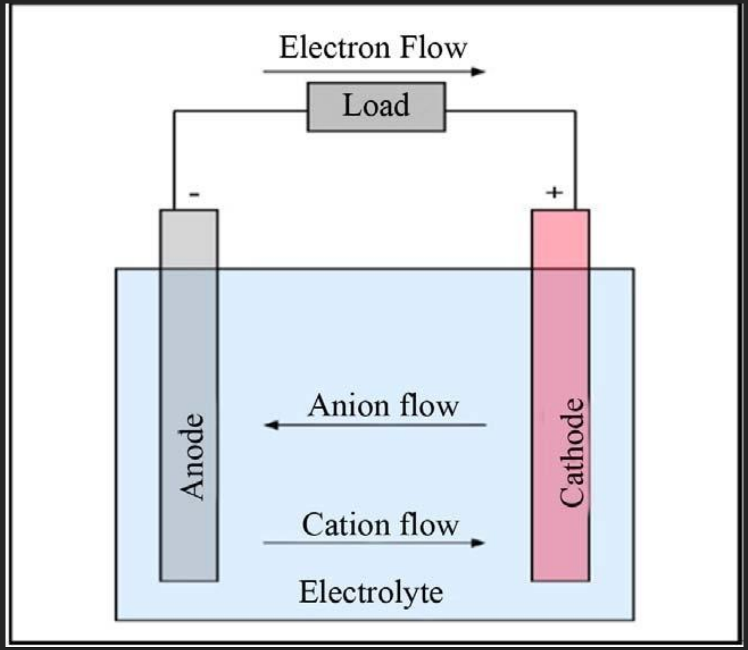


# Background

- An Italian physicist, Alessandro Volta, invented the first battery in 1800. Since then, battery technology has been used around the world.
- A battery is a collection of one or more cells, storing electrical energy for powering electrical devices.
- Working principle: chemical reactions create the flow of electrons within a circuit. The stored chemical energy is then converted into direct current electric energy.

# Types of batteries

- Primary (non-rechargeable)

convenient sources of power for portable electronics and devices. This includes radios, watches, toys, lights, camera, and more.

E.g. Alkaline batteries, Zinc – Carbon batteries and Lithium cells batteries.

- Secondary (rechargeable)

- The main advantage of these batteries is they can be recharged and reused.
- Secondary batteries usually cost more than primary ones. But considering they’re rechargeable, they can have a longer lifespan.
- Used for two applications: energy storage devices and applications where the battery is used and discharged as a primary battery

E.g. Nickel – Cadmium Batteries, Rechargable Alkaline batteries and Lithium-Ion Batteries.

# Primary Batteries

| Battery Type | Characteristics | Applications |
|---|---|---|
| Alkaline (Zn/Alkaline/MnO2) | Very popular, moderate cost, high performance | Most popular primary batteries |
| Magnesium (Mg/MnO2) | High capacity, long shelf life | Military and aircraft Radios |
| Mercury (Zn/HgO) | Very high capacity, long shelf life | Medical (hearing aids, pacemakers), photography |
| Lithium/Solid Cathode | High energy density, low temp performance, long shelf life | Replacement for button and cylindrical cells |
| Lithium/Soluble Cathode | High energy density, good performance, wide temp range | Wide range of applications with a capacity between 1 – 10,000 Ah |
| Lithium/Solid Electrolyte | Low power, extremely long shelf life | Memory circuits, medical electronics |
| Silver/Zinc (Zn/Ag2O) | Highest capacity, costly, flat discharge | Hearing aids, photography, pagers |
| Zinc – Carbon | Common, low cost, variety of sizes | Radios, toys, instruments |

# Secondary Batteries

| Battery Type | Characteristics | Applications |
|---|---|---|
| Rechargeable Alkaline | Low cost, long shelf life | Moderate power applications |
| Nickel-Cadmium | High power capability, long cycle life with low run time per charge, high cost | portable computers, drills, camcorders and other small battery-operated devices requiring an even power discharge |
| Lithium-ion | Popular, small sizes, need to recharge carefully | Health Instruments, Medical. Logistics and construction, Firefighting and Emergency, Military, EV. |
| Lead-acid | Widely used, low cost, high weight | ICE vehicles, construction, backup power for alarms and computer systems |

# Battery run time calculation

$E = C*V_{avg}$

Where E is the energy stored in watt-hours, C is the capacity in amp-hours, and Vavg is the average voltage during discharge. Yes, watt-hours is a measure of energy, just like kilowatt-hours. Multiply by 3600 and you get watt-seconds, which is also known as Joules.

Step 1. Back of the envelope

If the current drawn is x amps, the time is T hours then the capacity C in amp-hours is

$$C = xT$$

For example, if your pump is drawing 120 mA and you want it to run for 24 hours

$$C = 0.12 \text{ Amps} * 24 \text{ hours} = 2.88 \text{ amp hours}$$

# Battery run time calculation

Step 2. Cycle life considerations

It isn’t good to run a battery all the way down to zero during each charge cycle. For example, if you want to use a lead acid battery for many cycles you shouldn’t run it past 80% of its charge, leaving 20% left in the battery. This not only extends the number of cycles you get, but lets the battery degrade by 20% before you start getting less run time than the design calls for

$$C' = C/0.8$$

For the example above

$$C' = 2.88\ AH / 0.8 = 3.6\ AH$$

# Battery run time calculation

Step 3: Rate of discharge considerations

Some battery chemistries give much fewer amp hours if you discharge them fast. This is called the Peukart effect. This is a big effect in alkaline, carbon zinc, zinc-air and lead acid batteries. For example if you draw at 1C on a lead acid battery you will only get half of the capacity that you would have if you had drawn at 0.05C. It is a small effect in NiCad, Lithium Ion, Lithium Polymer, and NiMH batteries.

For lead acid batteries the rated capacity (i.e. the number of AH stamped on the side of the battery) is typically given for a 20 hour discharge rate. If you are discharging at a slow rate you will get the rated number of amp-hours out of them. However, at high discharge rates the capacity falls steeply. A rule of thumb is that for a 1 hour discharge rate (i.e. drawing 10 amps from a 10 amp hour battery, or 1C) you will only get half of the rated capacity (or 5 amp-hours from a 10 amp-hour battery). Charts that detail this effect for different discharge rate can be used for greater accuracy. For example the data sheets listed in /BB.htm

For example, if your portable guitar amplifier is drawing a steady 20 amps and you want it to last 1 hour you would start out with Step 1:

$$C = 20 \text{ amps} * 1 \text{ hour} = 20 \text{ AH}$$

Then proceed to Step 2

$$C' = 20 \text{ AH} / 0.8 = 25 \text{ AH}$$

Then take the high rate into account

$$C'' = 25 / .5 = 50 \text{ AH}$$

Thus you would need a 50 amp hour sealed lead acid battery to run the amplifier for 1 hour at 20 amps average draw.

# Battery run time calculation

Step 4. What if you don’t have a constant load? The obvious thing to do is the thing to do. Figure out an average power drawn. Consider a repetitive cycle where each cycle is 1 hour. It consists of 20 amps for 1 second followed by 0.1 amps for the rest of the hour. The average current would be calculated as follows.

$20*1/3600 + 0.1(3599)/3600 = 0.1044$ amps average current.

(3600 is the number of seconds in an hour).

In other words, figure out how many amps is drawn on average and use steps 1 and 2. Step 3 is very difficult to predict in the case where you have small periods of high current. The news is good, a steady draw of 1C will lower the capacity much more than short 1C pulses followed by a rest period. So if the average current drawn is about a 20 hour rate, then you will get closer to the capacity predicted by a 20 hour rate, even though you are drawing it in high current pulses. Actual test data is hard to come by without doing the test yourself.

# Battery run time calculation

Convert watts to amps

Actually, watts is the fundamental unit of power and watt-hours is the energy stored. The key is to use the watts you know to calculate the amps at the battery voltage .

For example, say you want to run a 250 watt 110VAC light bulb from an inverter for 5 hours.

Watt-hours = watts * hours = 250 watts * 5 hours = 1250 watt hours

Account for the efficiency of the inverter, say 85%

Watt-hours = watts * hours / efficiency = 1250 / 0.85 = 1470 watt-hours

Since watts = amps * volts divide the watt hours by the voltage of the battery to get amp-hours of battery storage

Amp-hours (at 12 volts) = watt-hours / 12 volts = 1470 / 12 = 122.5 amp-hours.

If you are using a different voltage battery the amp-hours will change by dividing it by the battery voltage you are using.

# batteries applications

- AGV wireless charging: https://www.agvnetwork.com/wireless-charging-for-agv-and-autonomous-mobile-robots
- Types of battery systems for robots: https://maker.pro/custom/tutorial/battery-systems-for-robots
- EV future batteries: https://www.greencars.com/guides/the-future-of-ev-batteries
- Types of drones batteries: https://www.grepow.com/blog/what-type-of-battery-does-drones-use/