HARDWARE: ELECTRICAL SUPPLY, BATTERIES (6-POWER MANAGEMENT)

BATTERY LIFE CALCULATOR

How to Calculate the Battery Runtime?

It would be wonderful never to have to charge a smartphone again. You're probably painfully aware of the fact that no battery lasts forever, though. This battery life calculator finds out the approximate runtime of your battery basing on the following formula:

$$\text{battery life} = \text{capacity} / \text{consumption} * (1- \text{discharge safety})$$

Where;

- **Capacity** is the capacity of your battery, measured in ampere hours. You can usually find this value printed on your battery.
- **Consumption** is the average current draw of your electronic device, expressed in amperes. (If you want to learn more about the electric current, make sure to check out the Ohm's law calculator!)
- **Discharge safety** is the percentage of your battery capacity that is never used. For example, if you use a LiPo battery to fly a drone, you should never discharge it below 20% – otherwise, it can be damaged. Our battery life calculator assumes a default discharge safety of 20%, but feel free to change it as you wish.

How Long Will a Battery Last: Sleep Mode?

- **Awake time** is simply the time that your device is not sleeping during one operational cycle – for example, 2 seconds.
- **Consumption** in sleep mode is the average consumption of your device in sleep mode, measured in amperes. This value is probably much lower than the consumption in awake mode.
- **Sleep time** is the time that your device spends sleeping during one operation cycle.

Based on the parameters listed above, the battery life calculator finds the average consumption according to the equation;

$$\text{average consumption} = (\text{consumption1} * \text{time1} + \text{consumption2} * \text{time2}) / (\text{time1} + \text{time2})$$

where index 1 describes the awake mode, and index 2 the sleep mode.

Steps To Calculate Battery Run-time

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

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

Steps To Calculate Battery Run-time

STEP 2 – Cycle Life Consideration

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

$$C' = 2.88 \text{ AH} / 0.8 = 3.6 \text{ AH}$$

Steps To Calculate Battery Run-time

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, 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.

Steps To Calculate Battery Run-time

STEP 4 – (If Don’t Have Constant Load)

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.

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

(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.

DIFFERENT TYPE OF BATTERIES: THEIR USES AND APPLICATIONS

PRIMARY (NON-RECHARGEABLE)

A primary battery is a convenient sources of power for portable electronics and devices. This includes radios, watches, toys, lights, camera, and more. Since they can't be recharged once they run out of power, they're the type to "discard immediately when discharged". In short, they can't be used again.

Primary batteries are inexpensive, lightweight, and convenient to use with no maintenance. The majority used in domestic applications are single cell type. They usually come in a cylindrical form, such as Alkaline batteries. They got their name from the electrolyte used in them: potassium hydroxide—a pure alkaline substance.

This type of primary battery is a chemical composed of zinc (Zn) and manganese dioxide (MnO2). It has a power density of 100 Wh/kg. Other shapes and sizes of a primary battery include a coin-shaped one, a.k.a. coin cell batteries. They are often used in torches, remotes, wall clocks, small portable gadgets, and more.

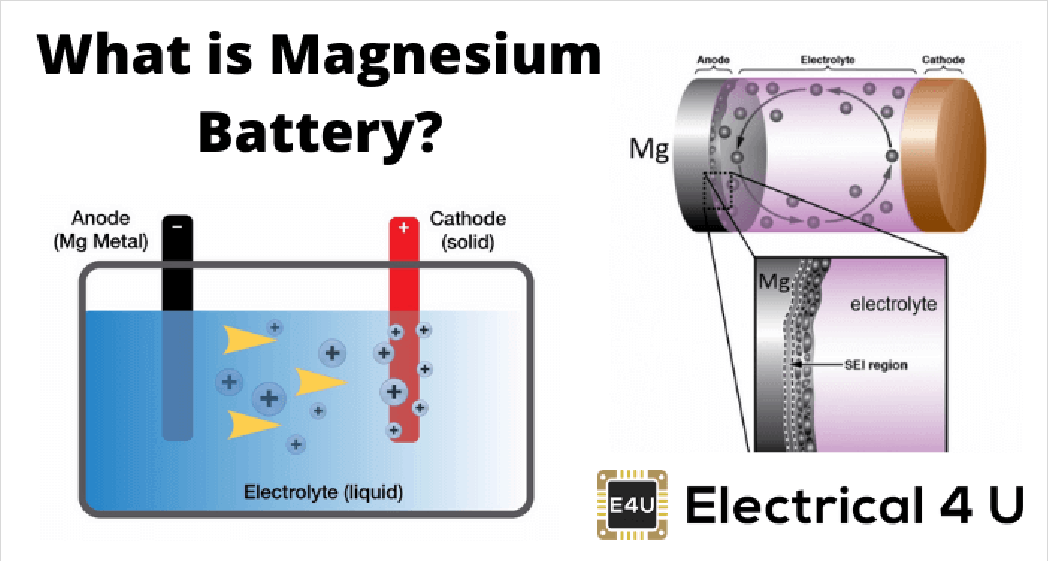
The chemical composition of a coin cell battery is also alkaline. But it also contains lithium and silver oxide chemicals. These compounds make this small battery more efficient, providing steady and stable voltage. It has a power density of 270 Wh/kg.

PRIMARY (NON-RECHARGEABLE)

Alkaline (Zn/Alkaline/MnO2)

Characteristics: Very popular, moderate cost, high performance
Applications: Most popular primary batteries

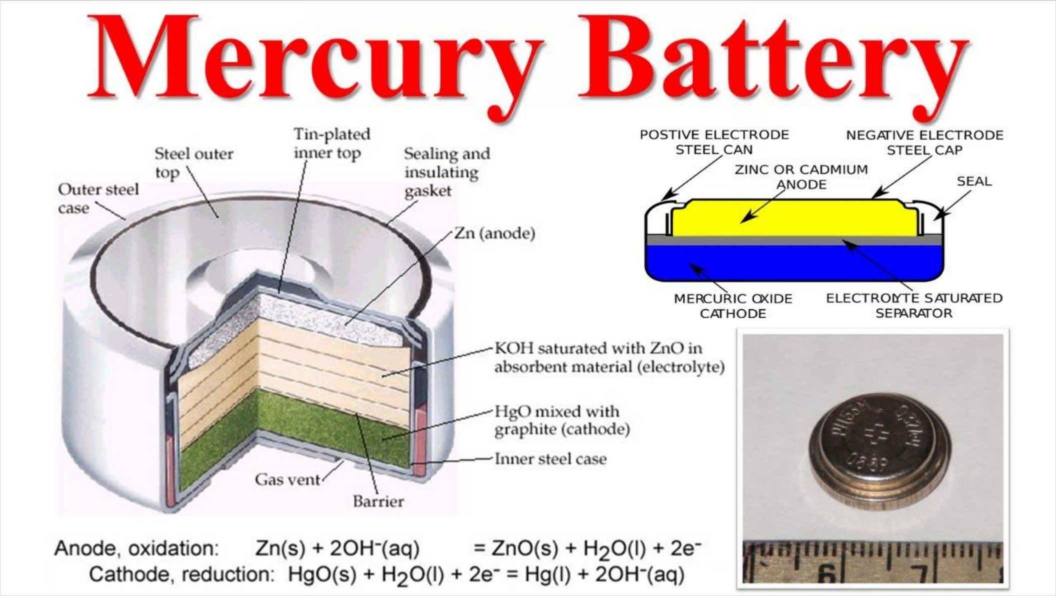
Magnesium (Mg/MnO2)



Characteristics: High capacity, long shelf-life
Applications: Military and aircraft Radios

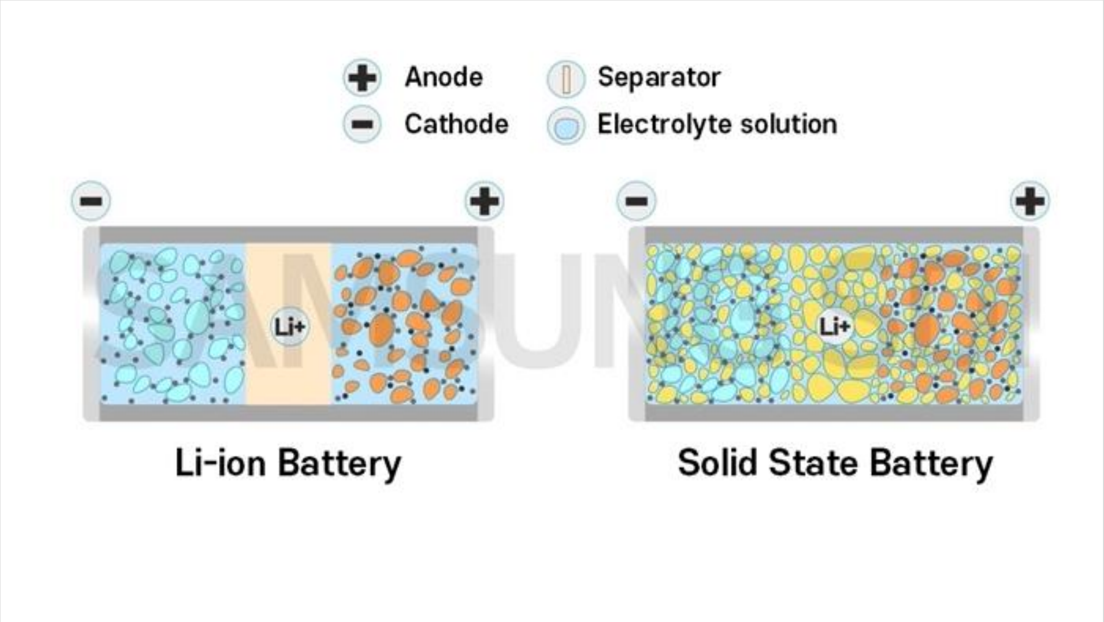
PRIMARY (NON-RECHARGEABLE)

Mercury (Zn/HgO)



Characteristics: Very high capacity, long shelf-life
Applications: Medical (hearing aids, pacemakers), photography

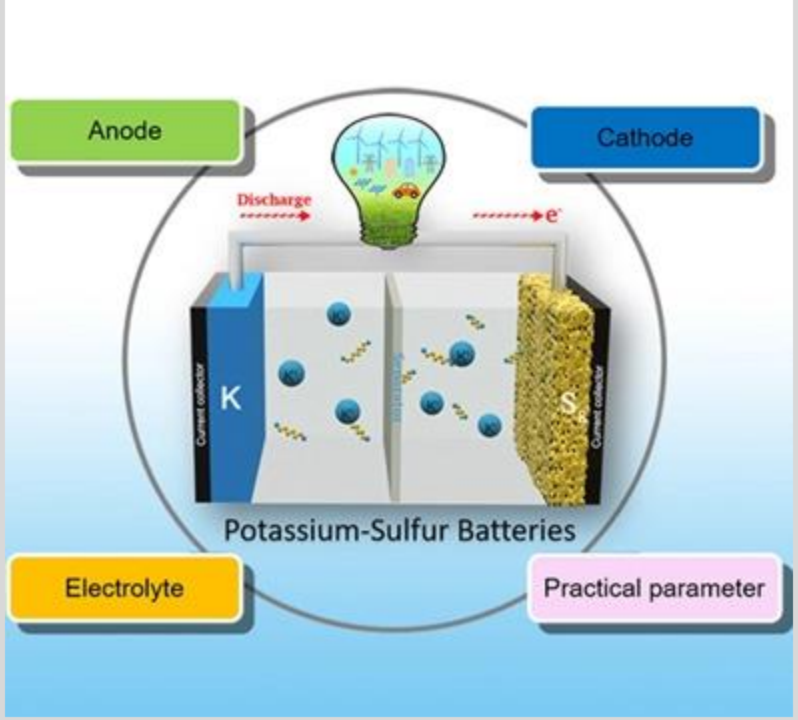
Lithium/Solid Cathode



Characteristics: High energy density, low temp performance, long shelf life
Applications: Replacement for button and cylindrical cells

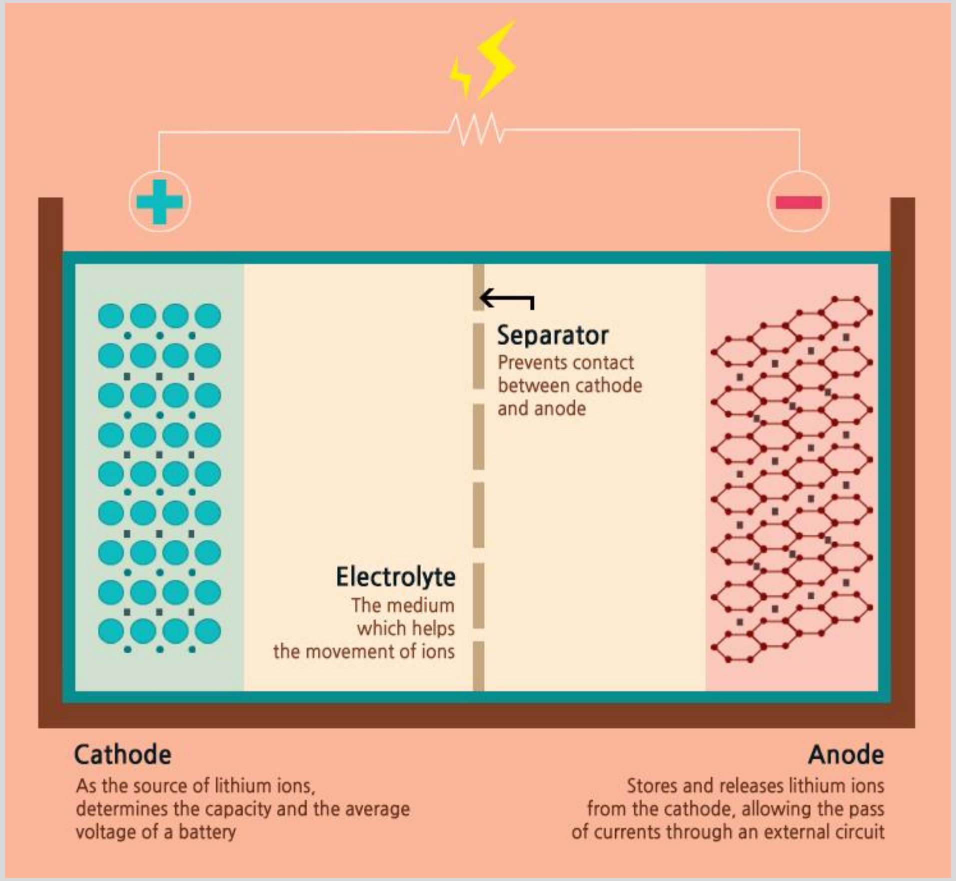
PRIMARY (NON-RECHARGEABLE)

Lithium/Soluble Cathode



Characteristics: High energy density, good performance, wide temp range
Applications: Wide range of applications with a capacity between 1 – 10,000 Ah

Lithium/Solid Electrolyte



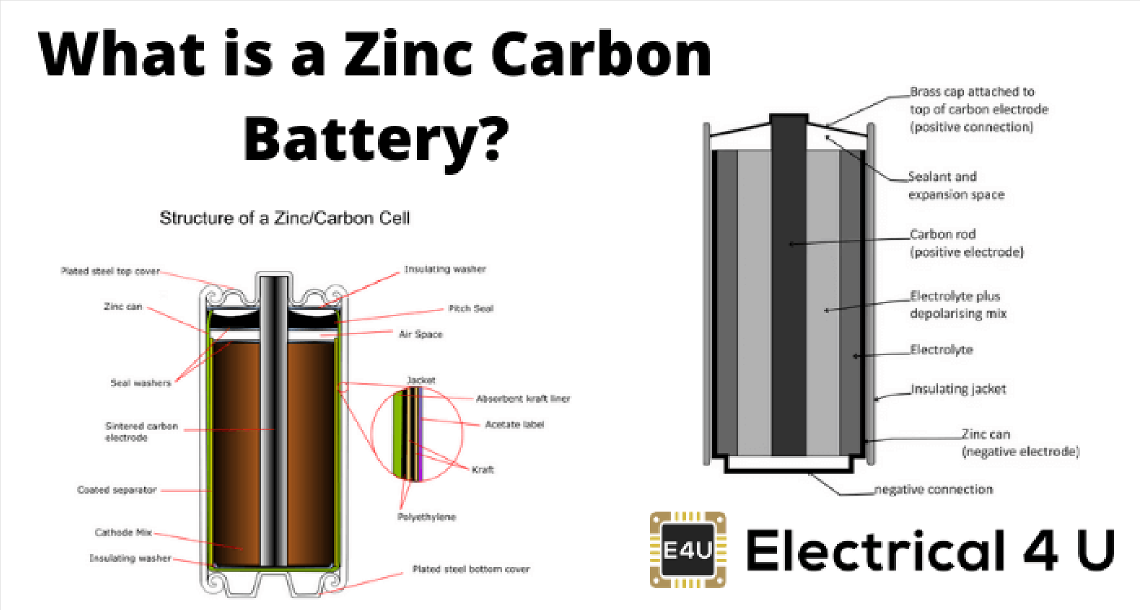
Characteristics: Low power, extremely long shelf life
Applications: Memory circuits, medical electronics

PRIMARY (NON-RECHARGEABLE)

Silver/Zinc (Zn/Ag2O)

Characteristics: Highest capacity, costly, flat discharge
Applications: Hearing aids, photography, pagers

Zinc – Carbon



Characteristics: Common, low cost, variety of sizes
Applications: Radios, toys, instruments

SECONDARY (RECHARGEABLE)

The main advantage of these batteries is they can be recharged and reused. Hence the other term: rechargeable batteries. 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
- applications where the battery is used and discharged as a primary battery

In the first application, secondary batteries supply and store energy for devices such as:

- Uninterrupted Power Supplies (UPS)
- Hybrid Electric Vehicles (HEV)

This means they're used as energy storage devices where they're electrically connected to the main energy source. At the same time, they're charged by it, supplying the needed energy. For instance, a UPS. It's a battery backup, especially for computers. It provides reserve power when your regular power source fails.

SECONDARY (RECHARGEABLE)

As for the second application, rechargeable batteries also work for portable electronics like:

- Mobiles
- Laptops
- Electric vehicles

Once they're completely or almost discharged, they can be recharged with a charging mechanism. For example, smartphone batteries. Most models have a lithium-ion battery that lives longer when charged often. This type of battery acts as their main power source, their primary one. But unlike the standard primary batteries, lithium-ion is rechargeable and reusable. For one, instead of discarding it, you pull out your cable wire or charger then plug it into a socket to charge it.

Another great example is the lead-acid batteries found in most cars and vehicles. It comes with a nominal voltage starting from 2V to 24V with a 7 Wh/kg power density. Plus, it's considered one of the four major types of secondary batteries, along with lithium-ion.

SECONDARY (RECHARGEABLE)

Lithium-ion battery

Lead-acid batteries

Characteristics: Lives longer, rechargeable, reusable
Applications: Smartphone batteries

Characteristics: Nominal Voltage from 2V to 24V with 7 Wh/kg power density
Applications: Car/Vehicle Batteries

SECONDARY (RECHARGEABLE)

Nickel – Cadmium Batteries

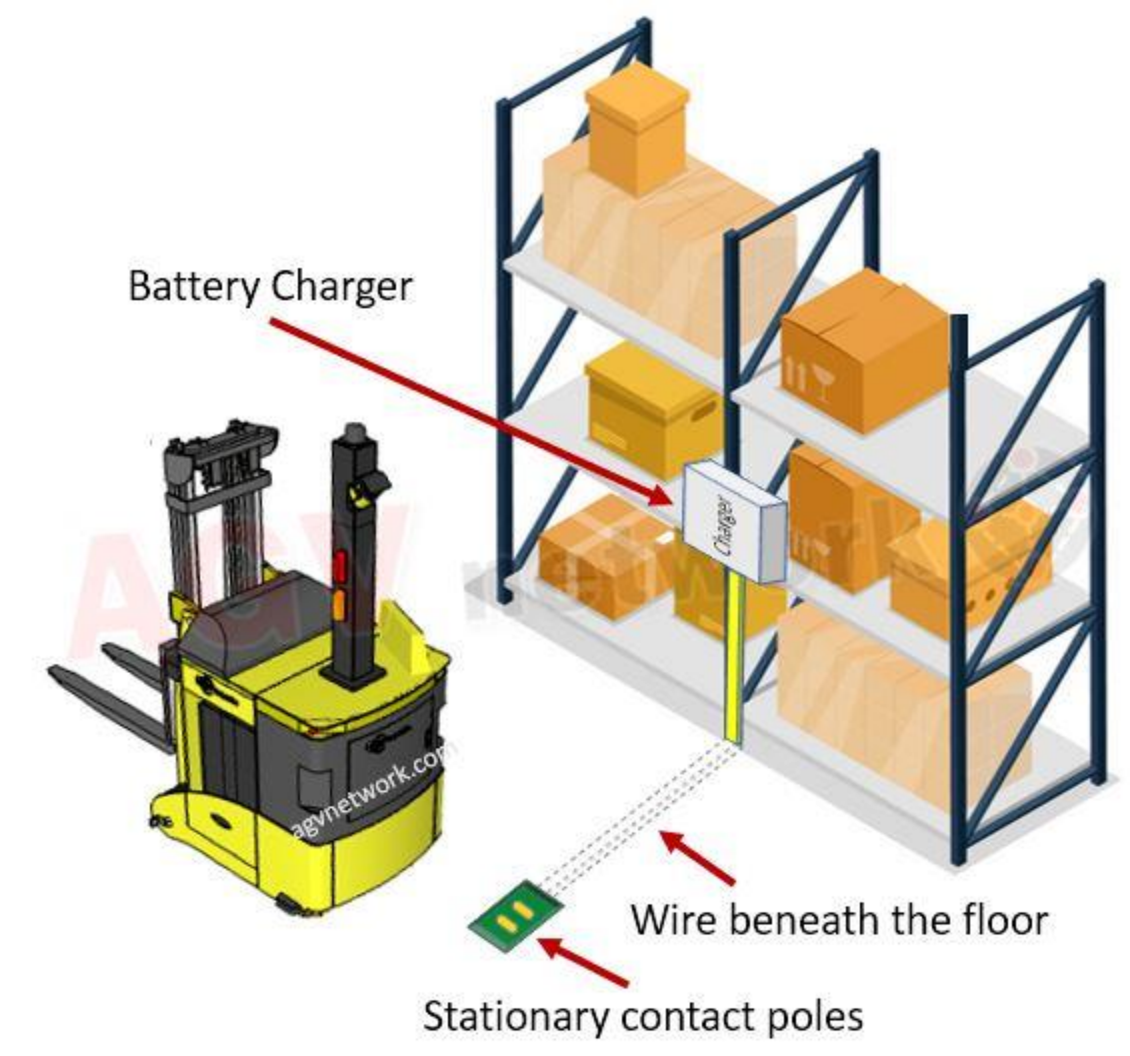
One of the oldest battery types available today. They have a very long life and are also very reliable and sturdy.

Nickel – Metal Hydride Batteries

They're a new type of battery, an extended version of Nickel – Hydrogen Electrode Batteries. Ideal use in aerospace applications (satellites).

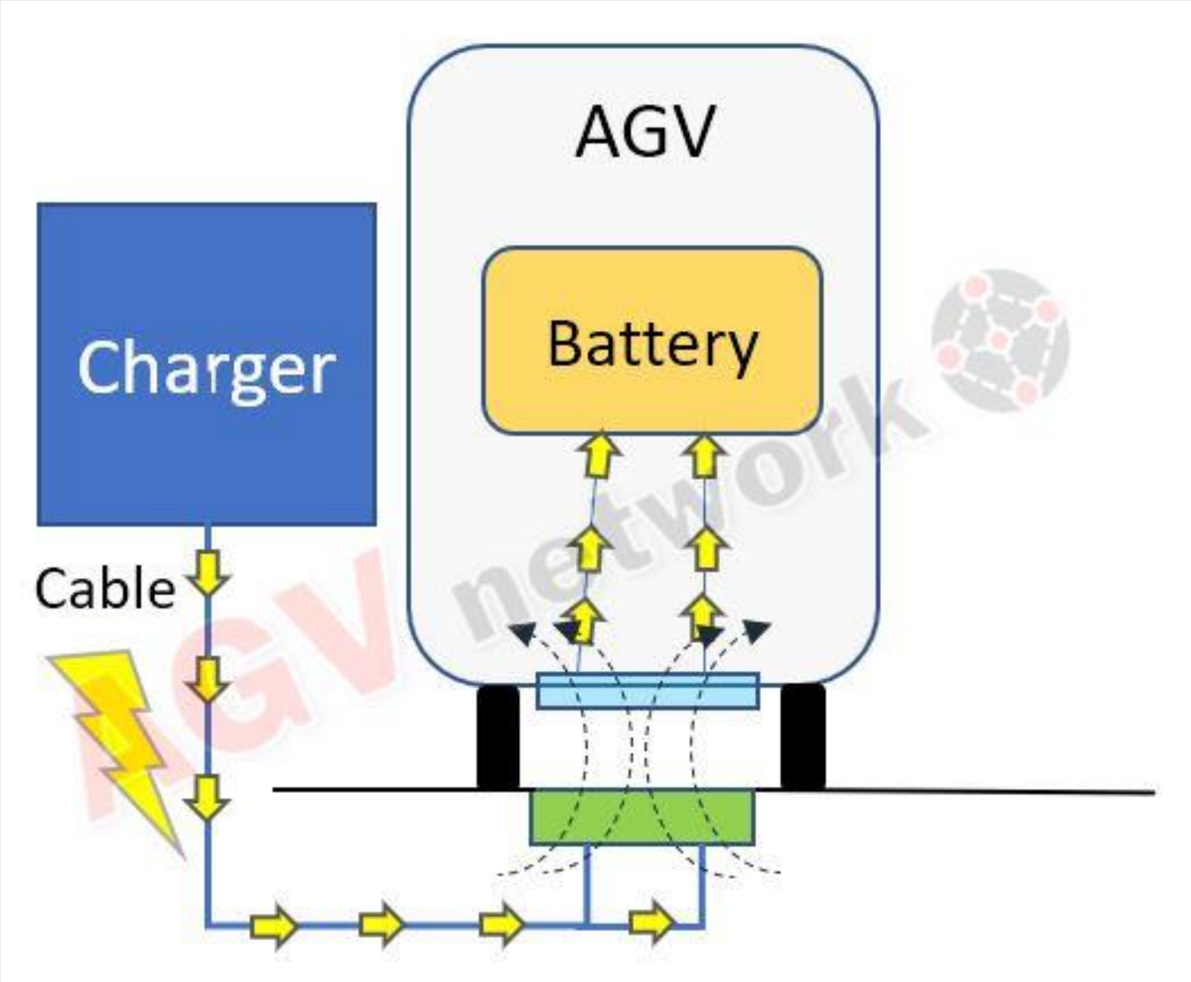
WIRELESS CHARGING AGV

Technical Basics About Wireless Charging For AGV



The AGV with the onboard charging poles arrives to the charging station. The charging station is composed by the stationary contact poles and the charger. The AGV moves down the contact poles, in general, tanks to a linear actuator. The poles (onboard and stationary) touch. The charger verifies the voltage differential and starts the charging cycle.

Technical Basics About Wireless Charging For AGV



The AGV with the onboard charging "coil" arrives to the charging station. The charging station is composed by the "stationary coil" and the charger. As soon as the onboard coil and the stationary coil overlap, the power is "magically" transferred without any contact thanks to the inductive principle.

Advantages of Inductive Wireless Charging for AGV Robot

- **High Efficiency 93%-95%**

This is the main advantage compared to traditional contact opportunity charging methods. Consider that standard opportunity contact charging efficiency is around 75%, in the best cases. This means that, with the wireless solution, you will need almost half of the power to charge your batteries, thus less energy costs. Of course, this saving will depend on the energy costs in your country.

- **Full Power Of High-Energy Streams Immediately After Start**

With the wireless systems, the battery starts to charge faster compared with contact charging solutions. In the contact solution, we have a charging module installed in the mobile robot that must move while starting/finishing to charge. This operation is time consuming. Maybe only few seconds, but those seconds add up over time, and time = money.

- **No Wear And Tear Or Maintenance As There Are No Contacts Involved**

As indicated, in the wireless solution, nothing moves. It means a simpler mechanical solution avoiding springs or linear actuators needed in the traditional contact opportunity charging. It is not easy to define the operational cost due to the “moving parts”, but you can be sure that in the long run, maintenance cost of the whole charging system will be lower with the wireless solution. Further, traditional contact copper electrodes tend to get dirty and create debris. Debris materials create spiked current arcs that could represent a problem for the robot electronics if not properly protected.

Advantages of Inductive Wireless Charging for AGV Robot

- **High Mobile Robot Positioning Tolerance Compared To Contacts And Omnidirectional Charging**

The contact charging poles must be in “contact”, so AGV positioning will depend on the shape and dimension of these poles (on board and on floor or wall). Moreover, with the contact charging poles, your Automated Guided Vehicle will probably be required to arrive to the charging station from one single direction. This feature is very interesting for Autonomous Mobile Robots (AMR), which do not follow a given path and can vary their trajectory depending on surrounding environment.

- **One single wireless charging system can supply power to different vehicles and batteries**

One wireless charging system can provide different Voltages for different battery types. This means you only need one charging system to charge different vehicles, for example an AGVs with a 48 V lithium-ion battery and an industrial truck with a 24 V lead-acid battery. All vehicles can use the same charging pad and the system autonomous chooses the right power for the vehicle.

- **Intelligent data transfer during wireless charging**

Some suppliers offer CAN connection allowing to transfer data during the charging process. All the relevant battery and vehicle data can be transferred into a cloud or directly to the AGV management system. This feature helps to manage and monitor the AGV fleet together with advanced programming of predictive maintenance in order to optimize your logistic process.

Drawbacks of Contactless Charging

- **Financial aspect**

The main drawback for contactless AGV charging is the financial aspect. Initial investment is relatively high compared to traditional contact opportunity charging.

- **Total Charging System Performance**

We have seen that inductive charging is more efficient . So, instead of having a 3kW charger you will probably only need a smaller one or you will need less time for charging.

- **Cash Flow is limited**

So, convincing someone about a higher initial investment is a hard task. You must think about it from a long-term business investment. You should always perform a detailed analysis to understand if wireless charging could represent a real advantage to your company's needs.

List of Manufacturers for Wireless Inductive Charging for AMR

- **B&PLUS**
- **Daihen**
- **Delta Energy Systems**
- **In2Power**
- **WiBotic**
- **Wiferion**