2.5 Batteries

2.5.1 Types of DC sources.

2.5.2 Types of cells, Primary and secondary cells (Mercury, silver oxide, Nickel- cadmium, etc.)

2.5.3 Lead acid batteries.

2.5.4. Solar cell. 2.5.5 Internal resistance of a cell.

2.5.6 Application of cell as constant voltage and constant current source.

A battery is essentially a source of DC electrical energy.
This then provides a source of electromotive force or emf to enable currents to flow in electric and electronic circuits. There are basically two classes of battery, **disposable and rechargeable**.

DC Power Sources and Batteries

Every electric circuit needs a power source, and the type of source dictates the functionality of the circuit. **A DC power source is a device or system that provides a consistent voltage and is used to power electric circuits.** The most common type of DC power source is a battery, like the batteries in laptops and cell phones.
A DC power source contains two **terminals** that are connected to a circuit in order to supply electric power. It provides a potential difference, or **voltage,** across these terminals. This potential difference *pushes* electrons into a circuit on at the negative terminal, also called the **anode**. Simultaneously, it *pulls* electrons out of the circuit at the positive terminal, also called the **cathode**.
All direct current circuits require DC power. This can come in form of a battery, a power supply, or an AC (alternating current) to DC converter. Computers (like laptops) that don't use dedicated power supplies use 'AC adapters' to convert AC power from a wall outlet into DC power. The adapter functions as the DC power source to the laptop.
Alkaline batteries are a common source of

What are DC Power Sources?

Power sources like batteries provide the electrical energy for circuits to function. Anything that uses a battery is relying on a DC power source.

Cell phones, laptops, cars, and cordless appliances like drills or even wine-bottle openers all use batteries as a source of direct current. If a device uses a battery as its' power source, internally it is comprised of DC circuits.

In fact, any thing that has a computer or digital circuit also relies on DC power sources. As the world becomes more automated and advanced, more devices rely on DC power sources to power the computer chips they use.

A lot of R & D has been invested into making our power sources as useful as possible, so the typical power source does not simply supply or accept electrons randomly; they are designed to do function with as much regularity as possible- without regulating the flow of electricity, it would be really difficult to design devices and tools to use that electricity.

Voltage, Current and Power

By necessity, all power sources involve three interlinked electrical properties: voltage, current, and power.

Although these topics are covered in much greater detail in specific tutorials, it is also useful to cover these topics with regard to power sources.

The primary job of a DC power source is to supply a steady amount of **voltage**; ideally, a power source would provide a specific voltage with zero fluctuation, forever. For example, an ideal 1.5 volt DC power source would always provide exactly 1.5 volts, forever. In contrast, a real-life 1.5 volt battery actually produces something close to 1.5 volts for most of its' life, and the voltage decreases as the battery becomes depleted.
Then the terminals of a power source are connected to each other by a wire or a circuit, the voltage produced by the power source results in an **electric current** that flows through the wire or circuit.
Because the voltage provided by the power source is constant (i.e. it does not change over time), the current produced is also constant. Therefore the type of current that flows in the circuit is **direct current**. Direct current is an electric current that always flows in the same direction.
In contrast, an alternating current (AC) power source provides an alternating voltage that changes over time like a sine wave. This results in an **alternating current** that flows back and forth in the circuit.
When current flows through a circuit, the circuit consumes **power**, which is equal to the voltage supplied by the power source times the current through the circuit:

$$\textit{Power} = \textit{Voltage} \times \textit{Current}$$

Power tells us how much energy is consumed by the circuit, which makes it an important quantity.

Real-life batteries actually produce a little over 1.5 V when they are new, and the voltage decreases as they are used. Whereas an ideal battery would produce 1.5 V until the moment of complete failure, real batteries slowly produce a lower and lower voltage. Further, the voltage supplied by batteries can vary slightly depending on the circuit being powered by the battery.

Batteries

The most commonly recognized DC voltage source is the **electric battery**– a device that uses chemical reactions to produce and receive electrons at accessible points that are located for convenience to the designers of our products.
These points are called **terminals**, which are electrically conductive areas on the outside of batteries, which are connected to the electrochemical cells inside the battery that produce and accept electrons.

The terminal connected to the electron producing cell is called the **anode** (i.e. the negative terminal), while the terminal connected to the electron accepting cell is called the **cathode** (i.e. the positive terminal).
Because the anode produces electrons, which are negatively charged, it is also called the **negative terminal**. The anode is often labelled with a minus (-) sign.
The cathode attracts electrons and is therefore called the **positive terminal**. The cathode is often labelled with a plus (+) sign.

Sometimes you may also hear the two terminals referred to as negative and positive **electrodes**, but this is not technically correct; the electrode is the conductor *inside* the battery that connects the terminals to the electrolytic fluid in the electrochemical cell.
Here's what a DC source (1.5 V battery) would look like in an electrical schematic:

Battery As a Power Source

Batteries are mobile sources of electric power. We use them to power our phones, computers, and, increasingly, our cars.

You don't need to understand the electrochemistry of batteries to use them and even to build circuits with them. Batteries are a great power source for circuit prototypes that aren't designed for AC applications and don't need to communicate with a computer. Small batteries are safe enough to be used by kids under adult supervision.

Just be aware: even a 9 volt battery can potentially start a fire. That's why it's so important to learn theory before or alongside any practical lab work. An experienced electronics enthusiast will know how to avoid potential dangers, so be careful until you get there.

Symbol for DC Power Sources

We've seen that batteries are often depicted as a circle with a positive (+) and negative (-) symbol indicating the positive and negative terminals:

This symbol indicates a generic DC power supply. It could be a battery, it could be a power supply 'box' that is plug into a wall outlet to convert AC power of a higher voltage into DC power at a low (1.5 V) voltage.

The ‘+’ symbol at the top of the source indicates that current flows *out* of the top side. The ‘-‘ symbol at the bottom of the source indicates that current flows *into* the bottom side. Thanks to Benjamin Franklin, we always define current as moving from positive to negative.
Another common symbol for DC power sources, which is a long line above a shorter line, with the longer line indicating the positive terminal:

- **Primary cell**: A primary cell or battery is the one that cannot easily be recharged after one use, and are discarded following discharge. ...
- **Secondary cell**: A secondary cell or battery is one that can be electrically recharged after its complete discharge.

What is a Battery?

A Battery is a chemical device that stores electrical energy in the form of chemicals and by means of electrochemical reaction, it converts the stored chemical energy into direct current (DC) electric energy. Alessandro Volta, an Italian Physicist, invented the first battery in 1800.

The electrochemical reaction in a battery involves transfer of electrons from one material to another (called electrodes) through an electric current.

Cell and Battery

Even though the term battery is often used, the basic electrochemical unit responsible for the actual storage of energy is called a Cell. A Cell, as just mentioned, is the fundamental electrochemical unit that is the source of electrical energy produced by conversion of chemical energy.

In its basic form, a cell typically contains three main components: two electrodes and electrolyte and also consists of terminals, separator and a container. Speaking of electrodes, there are two types of electrodes called the Anode and the Cathode.

The Anode is the negative electrode (also called the Fuel Electrode or the Reducing Electrode). It loses electrons to the external circuit and in the electrochemical reaction, it gets oxidized.

Cathode on the other hand, is the positive electrode (also called the Oxidizing Electrode). It accepts electrons from the eternal circuit and in the electrochemical reaction, it gets reduced. Hence, the energy conversion in a battery is due to electrochemical oxidation-reduction reaction.

The third important component of a cell is the electrolyte. An electrolyte acts as medium for transfer of charge in the form of ions between the two electrodes. Hence, the electrolyte is sometime referred to as Ionic Conductor. An important point to be noted here that the electrolyte is not electrically conductive but just have ionic conductivity.

A battery often consists of one or more “cells” that are electrically connected in either a series or parallel configuration to provide the necessary voltage and current levels.

Different Types of Batteries

Basically, all the electrochemical cells and batteries are classified into two types:

- Primary (non-rechargeable)
- Secondary (rechargeable)

Even though there are several other classifications within these two types of batteries, these two are the basic types. Simply speaking, Primary Batteries are non-rechargeable batteries i.e., they cannot be recharged electrically while the Secondary Batteries are rechargeable batteries i.e., they can be recharged electrically.

Primary Batteries

A Primary Battery is one of the simple and convenient sources of power for several portable electronic and electrical devices like lights, cameras, watches, toys, radios etc. As they cannot be recharged electrically, they are of “use it and when discharged, discard it” type.

Usually, primary batteries are inexpensive, light weight, small and very convenient to use with relatively no or less maintenance. Majority of the primary batteries that are used in domestic applications are single cell type and usually come in cylindrical configuration (although, it is very easy to produce them in different shapes and sizes).

Common Primary Battery Types

Up until the 1970’s, Zinc anode-based batteries were the predominant primary battery types. During the 1940’s, the World War II and after the war, Zinc – Carbon based batteries and they have an average capacity of 50 Wh / kg.

Most significant development in the battery technology took place during the 1970 – 1990 period. It is during this time, the famous Zinc / Alkaline Manganese Dioxide batteries were developed and they slowly replaced the older Zinc – Carbon types as the main primary battery.

Zinc – Mercuric Oxide and Cadmium – Mercuric Oxide batteries were also used during this period but due to the environmental concerns with respect to the usage of Mercury, these battery types slowly phased out.

It is during this period, where the development of batteries with Lithium as active anode material has been started and is considered a major accomplishment due to the high specific energy and longer shelf life of Lithium batteries over traditional Zinc batteries.

Lithium batteries are manufactured as button and coin cell for a specific range of applications (like watches, memory backup, etc.) while larger cylindrical type batteries are also available.

The following table shows different types of primary batteries along with their characteristics and applications.

Battery Type	**Characteristics**	**Applications**
Zinc – Carbon	Common, low cost, variety of sizes	Radios, toys, instrume nts
Magnesium (Mg/MnO_2)	High capacity, long shelf life	Military and aircraft Radios
Mercury (Zn/HgO)	Very high capacity, long shelf life	Medical (hearing aids, pacemakers), photography
Alkaline (Zn/Alkaline/MnO_2)	Very popular, moderate cost, high performance	Most popular primary batteries
Silver/Zinc (Zn/Ag_2O)	Highest capacity, costly, flat discharge	Hearing aids, photography, pagers
Lithium/Soluble Cathode	High energy density, good	Wide range of applications with capacity between 1 – 10,000 Ah

	performance, wide temp range	
Lithium/Solid Cathode	High energy density, low temp performance, long shelf life	Replacement for button and cylindrical cells
Lithium/Solid Electrolyte	Low power, extremely long shelf life	Memory circuits, medical electronics

Secondary Batteries

A Secondary Battery is also called as Rechargeable Battery as they can be electrically recharged after discharge. The chemical status of the electrochemical cells can be “recharged” to their original status by passing a current through the cells in the opposite direction of their discharge.

Basically, secondary batteries can be used in two ways:

- In the first category of applications, the secondary batteries are essentially used as energy storage devices where they are electrically connected to a main energy source and also charged by it and also supplying energy when required. Examples of such applications are Hybrid Electric Vehicles (HEV), Uninterrupted Power Supplies (UPS), etc.
- The second category of applications of secondary batteries are those applications where the battery is used and discharged as a primary battery. Once it is completely discharged (or almost completely discharged), instead of discarding it, the battery is recharged with an appropriate charging mechanism. Examples of such applications are all the modern portable electronics like mobiles, laptops, electric vehicles, etc.

Energy Density of secondary batterie are relatively lower than that of primary batteries but have other good characteristics like high power density, flat discharge curves, high discharge rate, low temperature performance.

Common Secondary Battery Types

Two of the oldest batteries are in fact secondary batteries called the Lead – Acid Batteries, which were developed in late 1850's and Nickel – Cadmium Batteries, which were developed in early 1900's. Until recent times, there are only two types of secondary batteries.

The first and the most commonly used rechargeable batteries are called Lead – Acid Batteries. They are based on the Lead – Lead Dioxide (Pb – PbO_2) electrochemical couple. The electrolyte used in these types of batteries is the very common Sulfuric Acid.

The second type of the rechargeable batteries are called Nickel – Cadmium Batteries. They are based on Nickel Oxyhydroxide (Nickel Oxide) as the positive electrode and Cadmium metal based negative electrode. Coming to the electrolyte, an alkaline solution of Potassium Hydroxide is used.

In the recent decades, two new types of rechargeable batteries have emerged. They are the Nickel – Metal Hydride Battery and the Lithium – Ion Battery. Of these two, the lithium – ion battery came out to be a game changer and became commercially superior with its high specific energy and energy density figures (150 Wh / kg and 400 Wh / L).

There are some other types of Secondary Batteries but the four major types are:

- Lead – Acid Batteries
- Nickel – Cadmium Batteries
- Nickel – Metal Hydride Batteries
- Lithium – Ion Batteries

Let us now briefly see about these battery types individually.

Lead – Acid Batteries

The lead-acid batteries are by far the most popular and most used rechargeable batteries. They have been a successful product for more than a century. Lead-acid batteries are available in several different configurations like small sealed cells with capacity of 1 Ah to large cells with capacity of 12,000 Ah.

One of the major applications od lead-acid batteries are in the automotive industry as they are primarily used as SLI Batteries (Starting, Lighting and Ignition).

Other applications of lead-acid batteries include energy storage, emergency power, electric vehicles (even hybrid vehicles), communication systems, emergency lighting systems, etc.

The wide range of applications of lead-acid batteries are a result of its wide voltage ranges, different shapes and sizes, low cost and relatively easy maintenance. When compared to other secondary battery technologies, lead-acid batteries are the least expensive option for any application and provide very good performance.Electrical efficiency of lead-acid batteries is between 75 to 80%. This efficiency value them suitable for energy storage (Uninterrupted Power Supplies – UPS) and electric vehicles.

Nickel – Cadmium Batteries

The Nickel – Cadmium Batteries or simply Ni-Cd Batteries are one of the oldest battery types available today along with the lead-acid batteries. They have a very long life and are very reliable and sturdy.

One of the main advantages of Ni-Cd Batteries is that they can be subjected to high discharge rates and they can be operated over a wide range of temperatures. Also, the shelf life of Ni-Cd batteries is very long. The cost of these batteries is higher that lead-acid batteries on per Watt-hour basic but it is less that other type of alkaline batteries.

As mentioned earlier, the Ni-Cd batteries use Nickel Oxyhydroxide (NiOOH) as Cathode and Cadmium metal (Cd) as anode. Typical consumer grade batteries come with an on-line voltage of 1.2V. In industrial applications, Ni-Cd are just second to lead-acid batteries due to their low temperature performances, flat discharge voltage, long life, low maintenance and excellent reliability.

Unfortunately, there is one major characteristic of Ni-Cd batteries called the “memory effect”, which is their only disadvantage. When Ni-Cd cells are discharged partially and then recharged, they lose their capacity progressively i.e., cycle-by-cycle. “Conditioning” is the process where the lost capacity of the batteries can be restored.

In this process, the cells are completely discharged to zero volts and then fully recharged.

Nickel – Metal Hydride Batteries

These are relatively new type of batteries are an extended version of Nickel – Hydrogen Electrode Batteries, which were exclusively used in aerospace applications (satellites). The positive electrode is the Nickel Oxyhydroxide (NiOOH) while the negative electrode of the cell is a metal alloy, where hydrogen is stored reversibly.

During charge, the metal alloy absorbs the hydrogen to form metal hydride and while discharge, the metal hydride loses hydrogen.

One main advantage of Nickel-metal hydride batteries over Ni-Cd batterie its higher specific energy and energy density. Sealed Nickel-metal hydride batteries are available commercially as small cylindrical cells and are used in portable electronics.

Lithium – Ion Batteries

The emergence of lithium-ion batteries in the last couple of decades has been quite phenomenal. More than 50% of the consumer market has adopted the use of lithium-ion batteries. Particularly, laptops, mobile phones, cameras, etc. are the largest applications of lithium-ion batteries.

Lithium-ion batteries have significantly high energy density, high specific energy and longer cycle life. Other main advantages of lithium-ion batteries are slow self-discharge rate and wide range of operating temperatures.

Battery Applications

In the last few decades, the usage of small sealed batteries in consumer applications has been exponential. Primary or rechargeable batteries in small form factor are being used in a huge number of appliances. Some of them are mentioned below.

- Portable Electronic Devices: Watches, Cameras, Mobile Phones, Laptops, Camcorders, Calculators, testing equipment (Multimeters).

- Entertainment: Radios, MP3 players, CD Players, all infrared remote controls, toys, games, keyboards.
- Household: Clocks, Alarms, Smoke Detectors, Flash lights, UPS, Emergency lights, tooth brushes, hair trimmers and shavers, Blood Pressure Monitors, Hearing Aids, pacemakers, portable power tools (drills, screw driver).
-
- **solar cell, also called photovoltaic cell**,
- any device that directly converts the energy of light into electrical energy through the photovoltaic effect. The overwhelming majority of solar cells are fabricated from silicon—with increasing efficiency and lowering cost as the materials range from amorphous (noncrystalline) to polycrystalline to crystalline (single crystal) silicon forms. Unlike batteries or fuel cells, solar cells do not utilize chemical reactions or require fuel to produce electric power, and, unlike electric generators, they do not have any moving parts.
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- International Space Station
- Solar cells can be arranged into large groupings called arrays. These arrays, composed of many thousands of individual cells, can function as central electric power stations, converting sunlight into electrical energy for distribution to industrial, commercial, and residential users. Solar cells in much smaller configurations, commonly referred to as solar cell panels or simply solar panels, have been installed by homeowners on their rooftops to replace or augment their conventional electric supply. Solar cell panels also are used to provide electric power in many remote terrestrial locations where conventional electric power sources are either unavailable or prohibitively expensive to install. Because they have no moving parts that could need maintenance or fuels that would require replenishment, solar cells provide power for most space installations, from communications and weather satellites to space stations. (Solar power is insufficient for space probes sent to the outer planets of the solar system or into interstellar space, however, because of the diffusion of radiant energy with distance from the Sun.) Solar cells have also been used in consumer products, such as electronic toys, handheld calculators, and portable radios. Solar cells used in devices of this kind may utilize artificial light (e.g., from incandescent and fluorescent lamps) as well as sunlight.
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- Explore ways to make solar cells more efficient, effective, and affordable
- See all videos for this article
- While total photovoltaic energy production is minuscule, it is likely to increase as fossil fuel resources shrink. In fact, calculations based on the world's projected energy consumption by 2030 suggest that global energy demands would be fulfilled by solar panels operating at 20 percent efficiency and covering only about 496,805 square km (191,817 square miles) of Earth's surface. The material requirements would be enormous but feasible, as silicon is the second most abundant element in Earth's crust. These factors have led

solar proponents to envision a future “solar economy” in which practically all of humanity’s energy requirements are satisfied by cheap, clean, renewable sunlight.

Definition of Internal Resistance

Internal Resistance Formula is a mathematical equation that can be used to calculate the resistance of an object in motion. Internal Resistance is caused by heat loss, friction, and other processes which act to slow down or stop the movement. Internal Resistance Formula is often used in engineering applications when designing engines and powertrains for cars or trucks, but it can also be applied in many other situations. In this article, I will explain what Internal Resistance Formula means, how it's calculated, and give examples with solutions so you understand how Internal Resistance works!

Constant current sources

deliver charge to the tissue in a controlled way, independent of potential impedance changes. Electrical stimulation generates faradaic and non-faradaic effects at the electrode surface. Faradaic effects at low currents do not necessarily generate tissue damage if full reversibility is given.

A constant voltage

is usually used **on circuits that require a steady voltage supply for their efficient operation**. For example, the constant voltage drivers are used for paralleled LED strip lighting due to the circuit design, which produces the most balanced current over the independent output channels.

3.6 Capacitance and capacitors. Capacitance of parallel plate capacitor. 3.7 Types and uses of capacitors. 3.8 Equivalent capacitance for series, parallel and series parallel combination of capacitors. 3.9 Energy stored in capacitors. 3.10 Colour code, tolerance and rating of capacitors. 3.11 Troubles in capacitors.

8. FILTER & COUPLING CIRCUITS (8 Hours) 8.1 Purpose and action of a filter circuit. 8.2 Principle of filter action. 8.3 Types of filter circuit LPF, HPF, K filter and m drive filter. 8.4 Band Pass filter (BPF) Band Stop filter (BSF) 8.5 Power supply filter. 8.6 Purpose and action of coupling circuit.