Power and Batteries

ECE 3400 - Fall 2017

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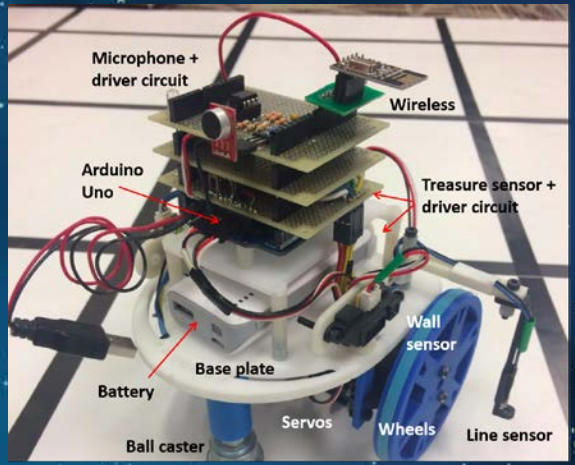
Systems That Need Power



Where Does Power Go?

Controllers & Drivers

- **3.3V - 5V, 9V - 12V**
- Microcontrollers
- Motor controllers
- Wireless modules

Actuators

- **3V, 6V - 12V**
- Servos
- DC motors
- Stepper motors

Sensors

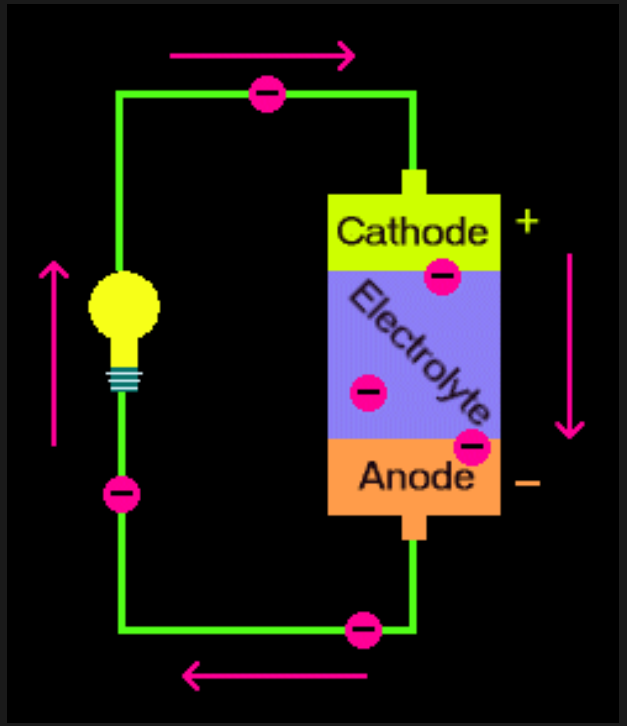
- **3.3V, 5V**
- LEDs
- IR sensors
- Speakers

How To Power Your System

- Batteries are the most commonly used source of power
- Many types of batteries, suited for different purposes
- Depending upon the system’s needs, you will have to consider several factors

Battery Basics

- A device that stored chemical energy and converts it into electrical energy on demand
- Three main parts:
  - Anode (fuel electrode)
  - Electrolyte
  - Cathode (oxidizing electrode)
- When the battery is connected:
  - Anode gives up electrons to the external circuit
  - Cathode accepts electronics from the circuit
  - Electrolyte carries electric current between anode and cathode in the form of ions



Battery Basics

- Each battery generally has a voltage and a power rating
  - A fully recharged battery will be ~15% above voltage rating
  - A fully discharged battery will be ~15% below voltage rating
- A fully charged battery will drop below its rating when driving heavy loads
  - DC motors!
- To increase battery voltage, wire multiple in series
- To increase battery current, wire multiple OF THE SAME VOLTAGE in parallel

Battery Basics

Capacity (XX mAh)

- milli-Ampere-hours
- Indicates how much electric charge battery can provide
- An 800 mAh battery can power a circuit that requires 1mA for 800 hours

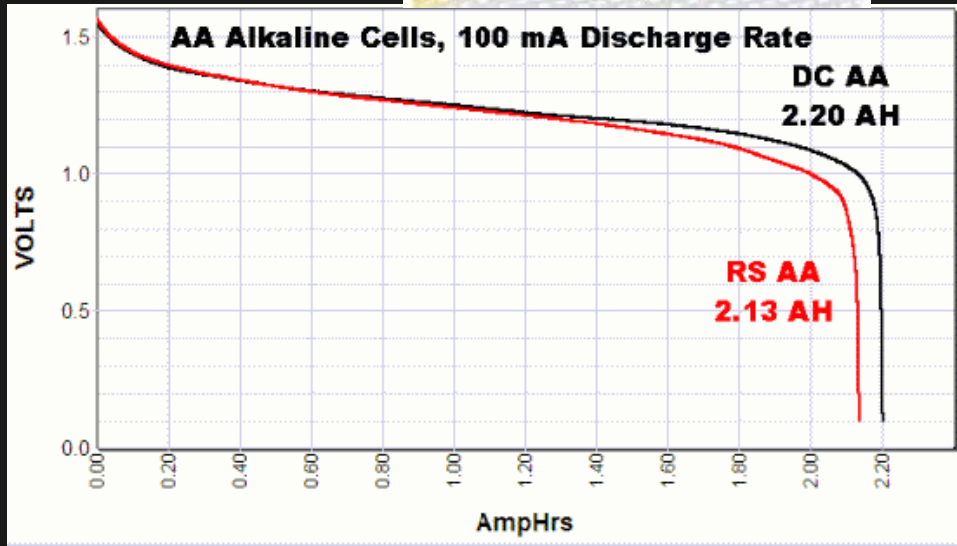
Dicharge Rate (C)

- C-rate is a measure of the rate at which the battery is discharged relative to its max capacity
- 1C rate means discharge current will discharge entire battery in 1 hour
- For a 100 mAh battery, that means a discharge current of 100 mA

Battery Basics

Alkaline Batteries

- Most commonly used
- Low power capacity
- Expensive to replace
- Not rechargeable!!!

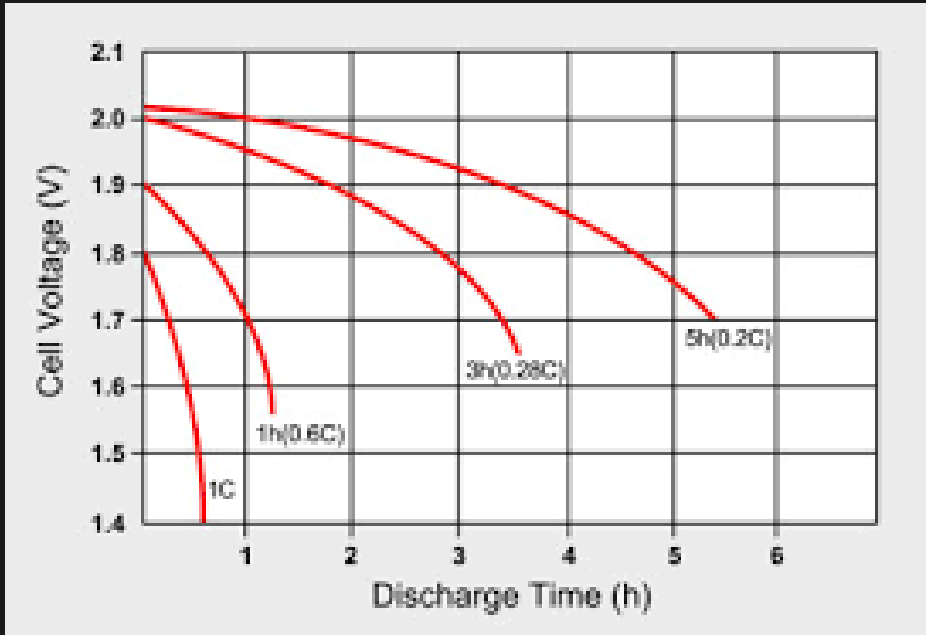


Battery Basics

Battery Types

Lead Acid

- Typically used in vehicles
- High power
- Inexpensive
- Designed to be more reliable
- Low energy per unit mass
- Poor performance in low temp
- Shorter life cycle

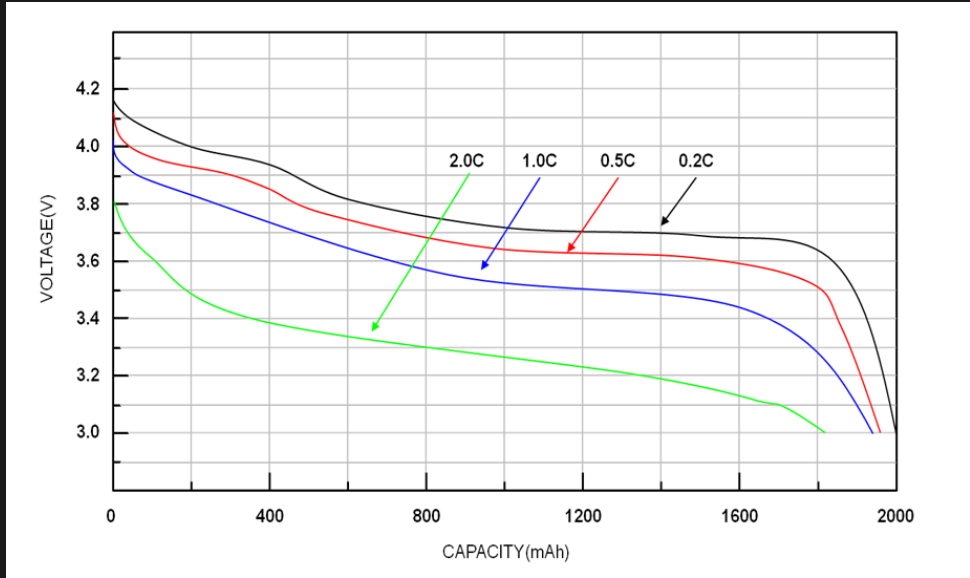


Battery Basics

Lithium (Li-Ion)

- Standard for portable power
- High energy capacity ~ NiMH
- Good power output rate ~ NiCd
- Weigh less than NiMH and NiCd
- Expensive

Battery Types

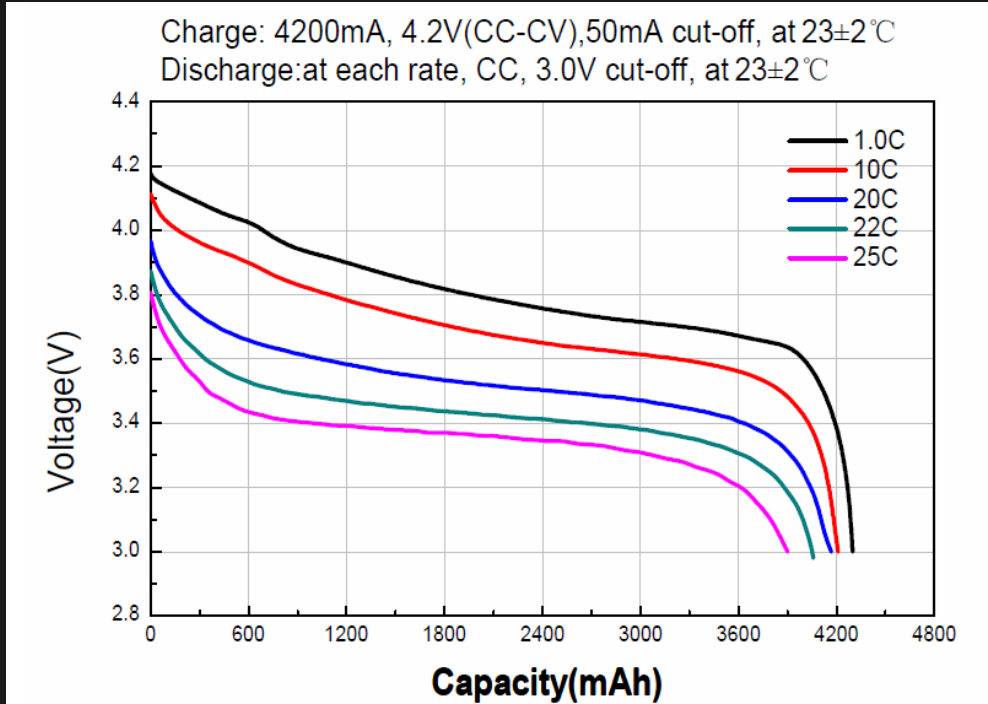


Battery Basics

Battery Types

Lithium Polymer (Li-Po)

- Higher current output (30A+)
- Lower power density than Li-Ion

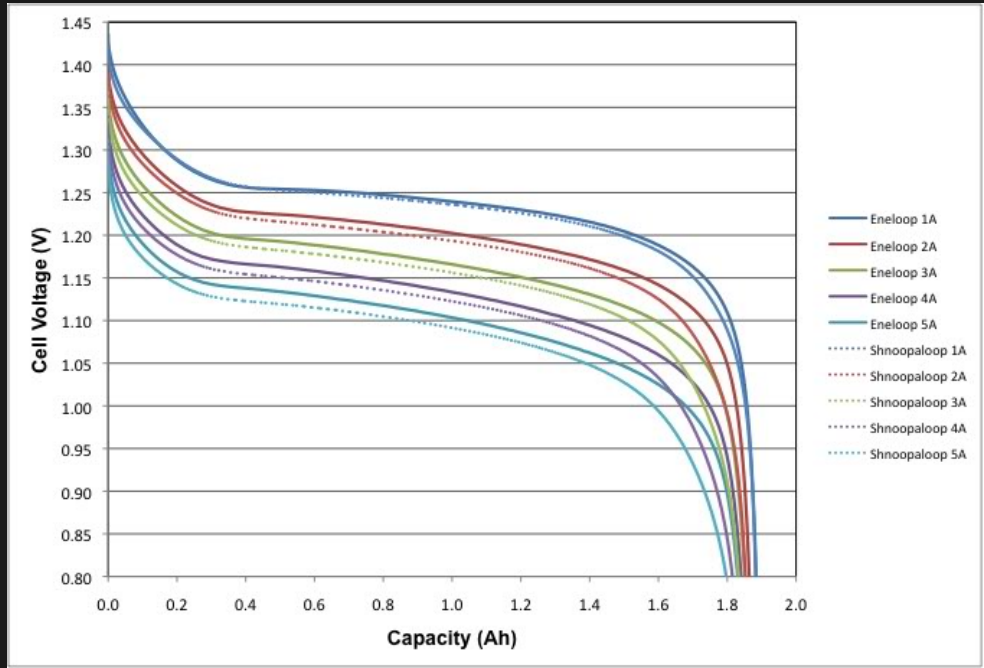


Battery Basics

Battery Types

NiCd (Nickel Cadmium)

- Good for small-medium size robots
- Highest current output
- More affordable than NiMH
- Recharged within 1-2 hours
- However, stores less and less energy after every charge
- Recycling/disposal must be careful because cadmium is very toxic

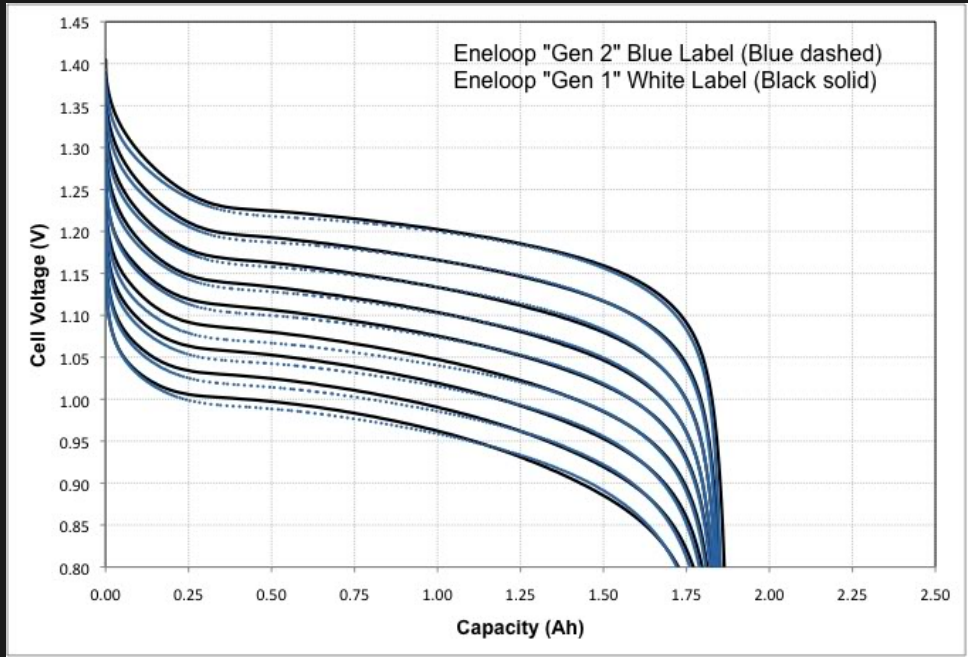


Battery Basics

Battery Types

NiMH (Nickel Metal Hydride)

- Can be recharged multiple times
- Good current output
- Highest energy capacity ~ Li-Ion
- Take long to charge
- High self-discharge rate



Factors To Consider

How much power do your components require?

- Voltage do they run at?
- Current they can handle?

What is the physical size of your system? How much can it weigh? Batteries are often the heaviest part!

What is your system’s cycle lifetime? How long does it need to run for?

Safety requirements?

Factors To Consider

All of these factors will decide:

- The type of battery
- The required power rating
- The size of the battery

AND

- Can you power everything using one power source?
  - Arduino and motors both powered using single 5V battery pack
- Will different components require separate power sources?
  - Example: Arduino powered with 9V battery, motors with 6V battery pack

Method 1 - Same Power Source

Multiple components powered using the same power source.

Advantages

- Need to charge only one power source
- System is likely less bulky

Disadvantages

- Powering all components is a more complex task
  - May require voltage regulation (unless your component already does that, like the Arduino)

Method 2 - Separate Power Sources

Different components powered using different power sources.

Advantages

- Requires less design time
- May be more efficient

Disadvantages

- Different parts of system run out of power at different times
- Multiple batteries to recharge
- Adds bulk to the system

Distributing and Regulating Power

- Using a single power source to power many components?
- Couldn’t find a power source with the voltage rating your component needs?
- You may need to use voltage regulators!

Distributing and Regulating Power

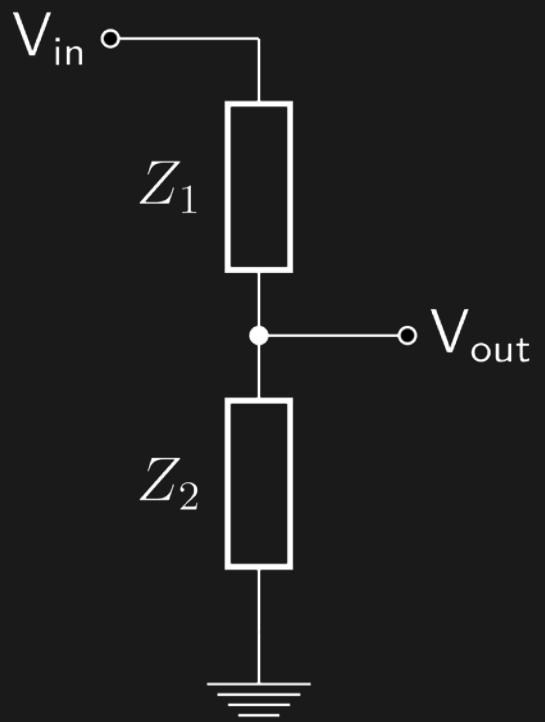
Voltage Dividers

Pros

- Good for producing an intermediate voltage from higher supply voltage

Cons

- Output changes with supply voltage (line regulation)
- Output changes with load (load regulation)
- Has a large impedance

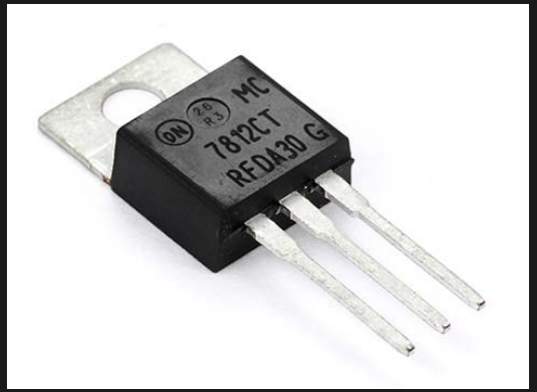


$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$

Distributing and Regulating Power

Voltage Regulators

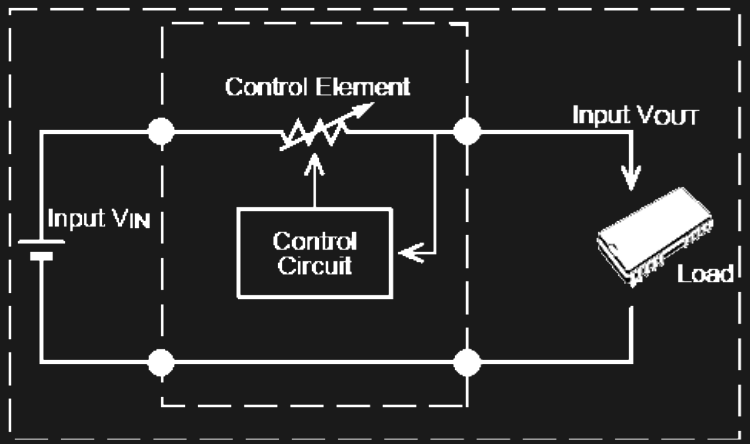
- Better line regulation and load regulation
  - Output is more stable compared to input
  - Better if your load is higher
- Lower impedance generally
- Two kinds:
  - Linear
  - Switching



Distributing and Regulating Power

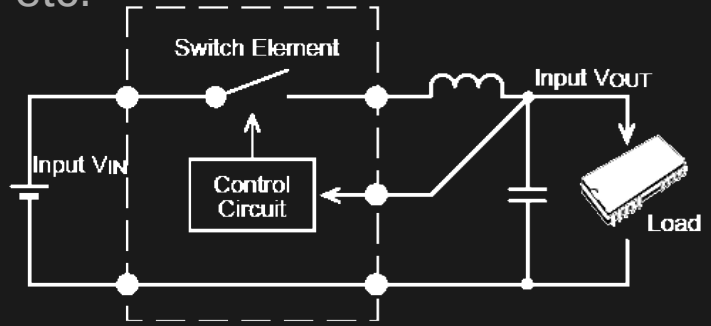
Linear Voltage Regulators

- Linear component (like resistive load) used to regulate output



Switching Voltage Regulators

- Switching component used to transform incoming power into pulsed voltage, which smoothed over using capacitors, inductors etc.



Distributing and Regulating Power

Voltage Regulators

	Linear Regulators	Switching Regulators
Function	Buck (step-down)	Buck and boost (step-up), inverts
Efficiency	Depends upon load current and battery voltage over time	High except at low load currents (µA)
Dissipation	High	Low
Complexity	Low - req regulator and bypass capacitor → cost lower	High - req regulator, inductor, diode, filter caps, and even FETs → cost higher
Noise	Low (no ripple, no noise)	Medium (ripple due to switching rate)

References & Resources

www.robotshop.com

www.azorobotics.com

www.societyofrobots.com

Voltage Regulation Basics