MINN KOTA®

MINN KOTA

PRESENTATION TOPICS

Electric Current

Batteries

Boat Wiring

Motor Theory

MINN KOTA

Electric Current

AC and DC Current

Measurements

Series and Parallel

MINN KOTA

AC and DC Current

~ AC Current:

- Flow of electrons switches directions (US household wiring does this 60 times/second)
- Typically uses a “hot” and “neutral” wire
- Efficiently uses higher voltages, can be transmitted very long distances
- Must be used as it is created; cannot be stored
- Typically, more dangerous to work on
- **Not used for trolling motors; only mentioned for comparison**

MINN KOTA

AC and DC Current

⎓ DC Current:

- Flow of electrons in one direction
- Typically uses a + positive and - negative wire
- Can be efficiently stored and used later (Battery)
- Relatively safe to work with
- ✘ Not good for transmitting long distances

Measurements

Amp (A)

Current is measured in amps. A current flow of 1 amp equals 6,241 quintillion electrons per second.

MINN KOTA

Measurements

Volt (v)

Electrical potential is measured in volts. One volt of potential will do one Watt worth of work at 1 amp.

If you think of electricity flowing like water Amps or current is the volume moving through, Volts would be the pressure pushing that volume.

Measurements

Watt (w)

The Watt is a measurement of power. When working in electricity the Watts are easily found by Volts x Amps or vA (W=vA). One Horsepower is roughly 745 watts.

Measurements

Hour (h)

A measure of time of course. A better understanding of stored power available or total power consumed is either amp x hours (Ah) or watt x hours (wh). Batteries are often rated in Ah to determine their capacity.

Measurements

Ohm (Ω)

The measure of electrical resistance. As resistance increases the power lost to heat in that circuit also increases; power loss causes a decrease in voltage and can show up as lower current.

MINN KOTA

Pop Quiz

A 55-pound thrust motor is a 12-volt motor and draws 50 amps on high.

What is the minimum runtime that should be expected when connected to a 105 Ah battery?

Roughly 2 hours. 85%(105Ah/50h) = 1.785h

How Many Horsepower does it have?

Less than 1. 12v x 50A = 600w; 600w/745w = .805hp

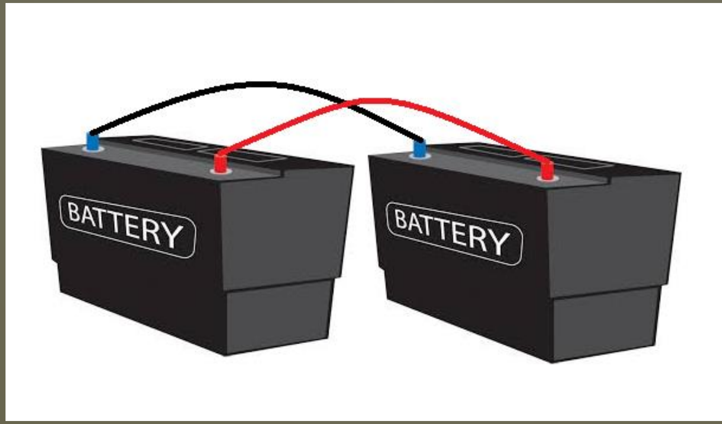
Series and Parallel

There are two ways multiple Electric items can be arranged within a circuit: Series and Parallel.

Wiring to the outboard and various accessories on a boat should all be parallel; we'll focus on how these two types of circuits apply to trolling motor batteries.

Series and Parallel

Wired in parallel voltage remains the same, current changes.

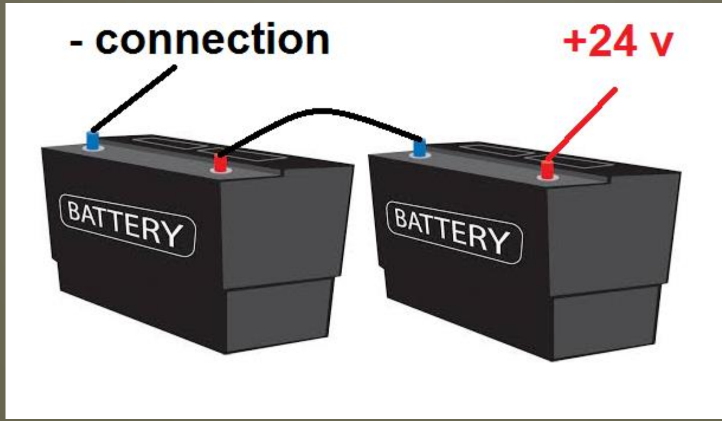


So, (2) 105 Ah 12v batteries wired together in parallel become (1) 210 Ah 12v battery

MINN KOTA

Series and Parallel

Wired in series current remains the same, voltage changes.



So, (2) 105 Ah 12v batteries wired together in series become (1) 105 Ah 24v battery

MINN KOTA

Batteries

History

YouTube Video

Battery Types

Lead/Acid Battery Chemistry

LiFePO4 Battery Chemistry

MINN KOTA

Battery History

FACT: Gaston Planté (1834–1889) was the French physicist who invented the lead-acid battery in 1859. The lead-acid battery eventually became the first rechargeable electric battery marketed for commercial use.

His early model consisted of a spiral roll of two sheets of pure lead separated by a linen cloth, immersed in a glass jar of sulfuric acid solution.

http://www.youtube.com/watch?v=rhIRD5YVNbs

Battery Types

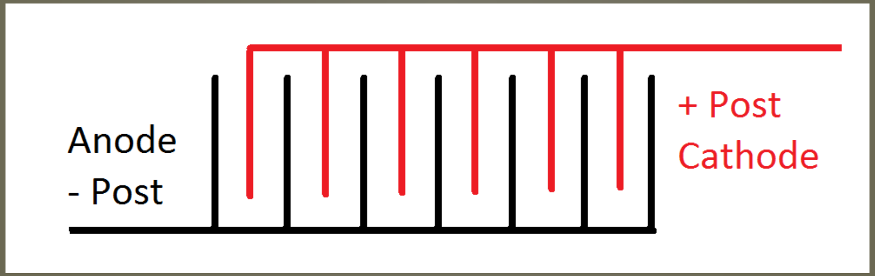
All batteries consist of three parts:

- Anode (- post)
- Cathode (+ post)
- Electrolyte

In any lead acid battery the anode is composed of “sponge” lead, the cathode is lead dioxide and the electrolyte is a dilute solution of 33% sulfuric acid.

Lead/Acid Battery Construction

Each battery cell is constructed with the anodes and cathodes arranged in a sandwich fashion. One example may look like this:



Electrolyte bridges the space between the Anode and Cathode

Each cell produces about 1.5 to 2.2 volts.

MINN KOTA

Pop Quiz

How many cells in a 12 volt Lead/Acid battery?

6

In series. 6(1.5 to 2.2) = 9 to 13.2

What Happens if an anode and cathode are in direct contact?

A dead cell. A "Load Test" will find this condition.

MINN KOTA

Lead/Acid Battery Types

Minn Kota recommends using a
Group 27 or Larger Deep Cycle Marine Battery

The most common Lead/Acid, Deep Cycle Marine Batteries:

Flooded Lead Acid
AGM (Absorbed Glass Mat)
Gel Cell

Lead/Acid Battery Types

Flooded Lead Acid:

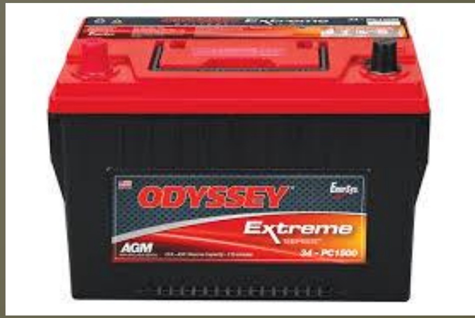
- Anode and Cathode separated by “paper”
- Electrolyte “bath” that the plates are submerged in
- Removable caps allow for maintenance of the electrolyte
- ✗ Requires maintenance

MINN KOTA

Lead/Acid Battery Types

AGM (Absorbed Glass Mat):

- ❖ Anode and Cathode separated by fiberglass mat that has Electrolyte soaked into it (like a sponge)
- ❖ Maintenance Free
- ✘ More Expensive
- ✘ Some have lower than expected capacity



MINN KOTA

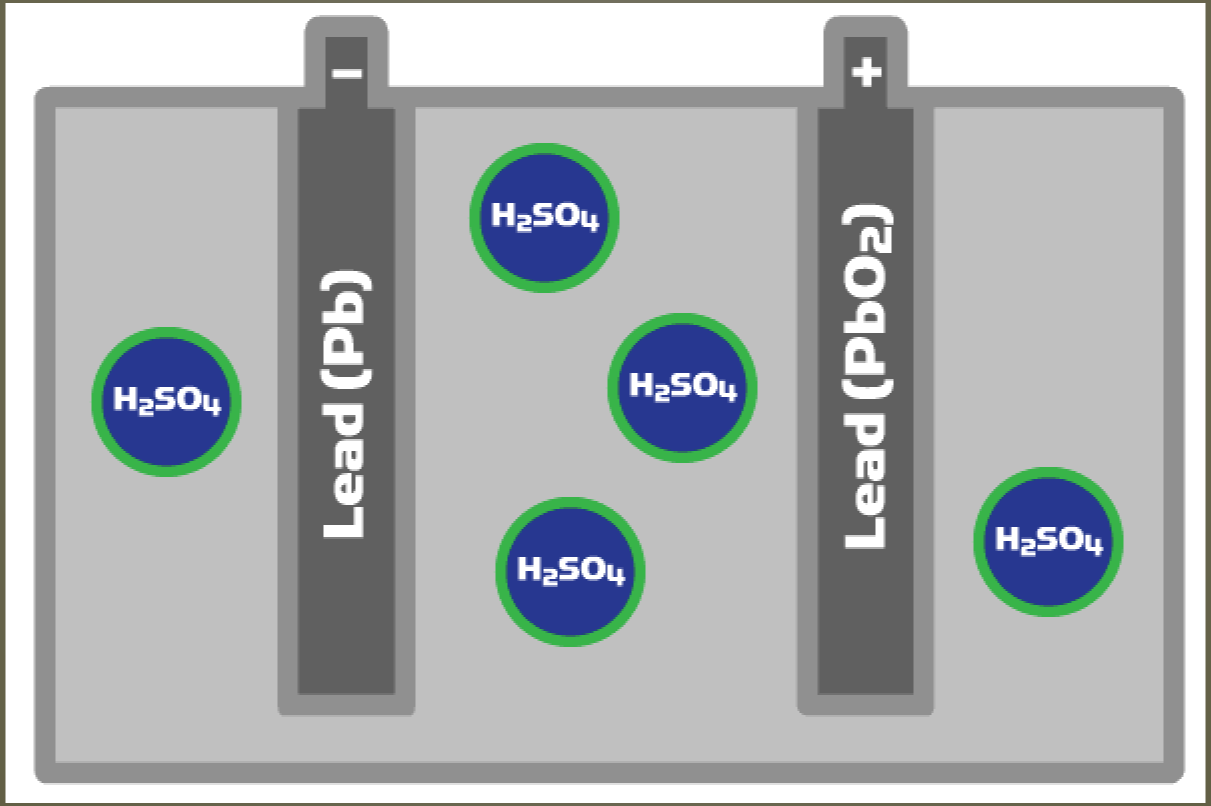
Lead/Acid Battery Types

Gel Cell:

- ❖ Electrolyte mixed with silica to immobilize it.
- ❖ Maintenance Free
- ✘ More Expensive
- ✘ Hard to Find (in large sizes)
- ✘ Special Charging requirements (lower voltage)

Lead/Acid Battery Chemistry

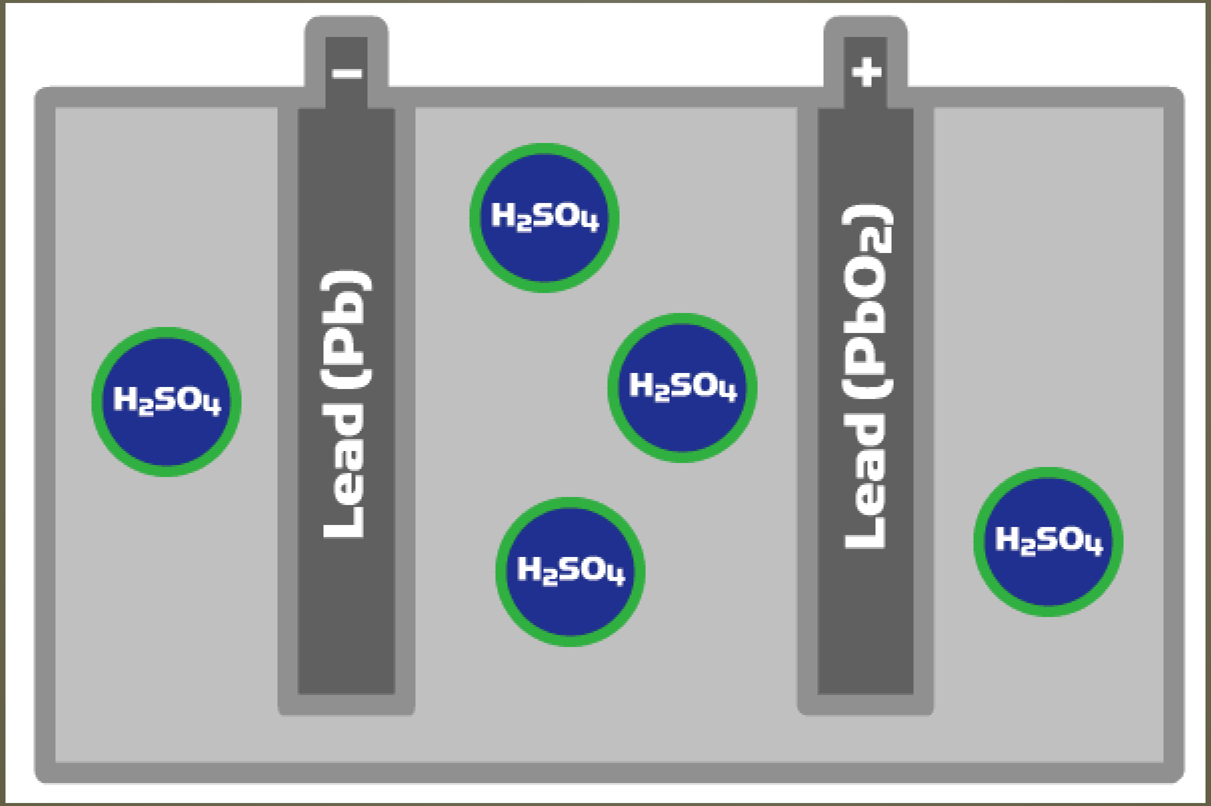
Charged Battery:



MINN KOTA

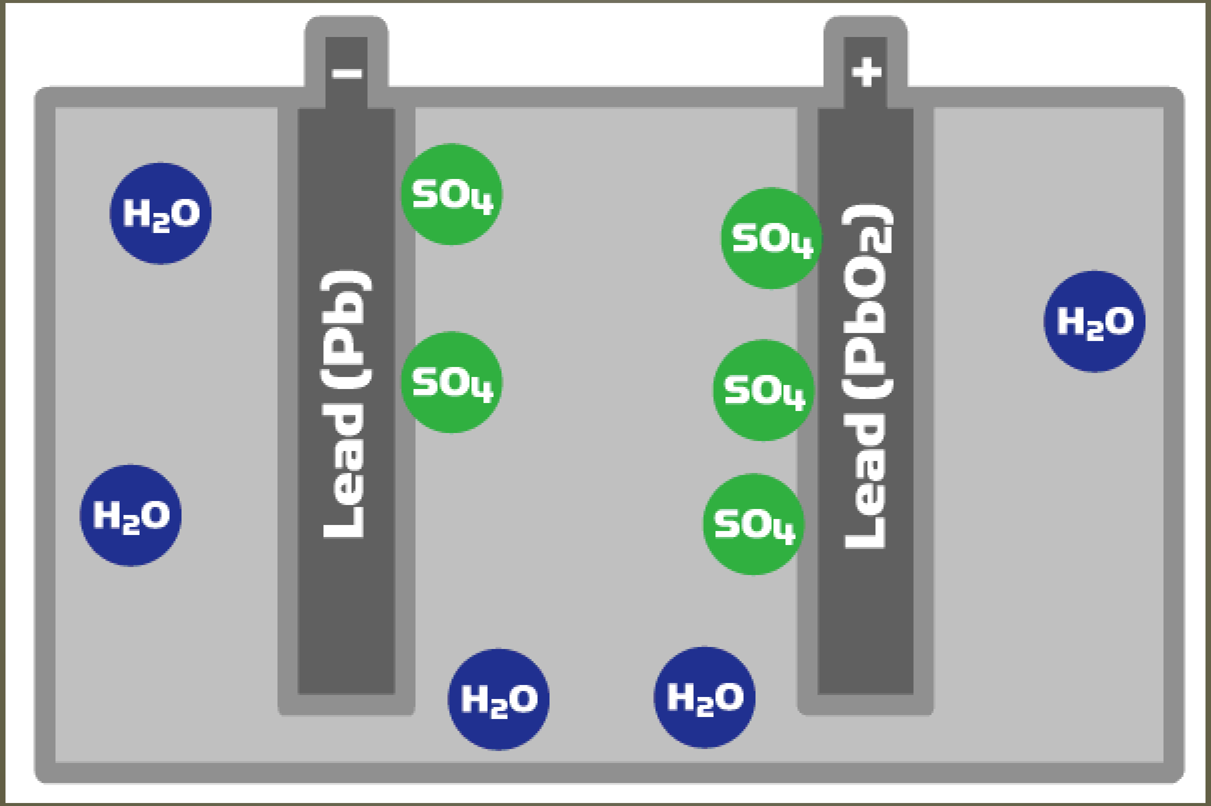
Lead/Acid Battery Chemistry

Discharging Battery:



Lead/Acid Battery Chemistry

Charging Battery:



MINN KOTA

Lead/Acid Battery Chemistry

So…

- Discharged Batteries are filled with mostly water.
  - A battery at 100% charge would withstand temperatures down to -92^o Fahrenheit before freezing
  - A battery at 40% charge could freeze at approximately +16^o Fahrenheit

MINN KOTA

Lead/Acid Battery Chemistry

Over time some acid will permanently combine with lead creating a sulfate. Less acid will mean fewer useable Amp Hours.

In a flooded lead acid battery testing the specific gravity of the electrolyte will tell you how much battery life is left; this is done with a hydrometer.

With the battery at a temperature of 77-80° F the specific gravity of the electrolyte in a fully charged battery will be 1.265 or slightly higher. Specific gravity readings should not vary more than .05 between cells.

Lithium Battery Chemistry

Lithium Iron Phosphate, or LiFePO4 is the most common "Drop-in" Lithium Chemistry for Replacement of Lead Acid Batteries.

A LiFePO4 Cell 3.0-3.3V, so a 4 Cell LiFePO4 Battery has a nominal voltage that is similar enough to a 6 Cell Lead/Acid Battery to be functional.

Lithium Battery Chemistry

Where the reactions in a Lead/Acid Battery are:

H_2SO_4 + Pb – (2) electrons = $PBSO_4$ + H_2O

H_2SO_4 + PbO_2 – (2) electrons = $PBSO_4$ + H_2O

The same in a LiFePO4 Battery are:

$LiFePO_4$ = $FePO_4$ + Li – 1 electron

Li + C6 + 1 electron = LiC6

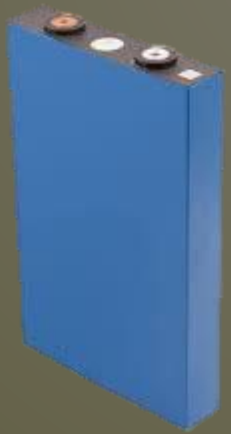
Where C6 is the Graphite anode, and the freed Li atoms are positive ions.

All of this just to show… On one level Li-ion Batteries are Batteries

MINN KOTA

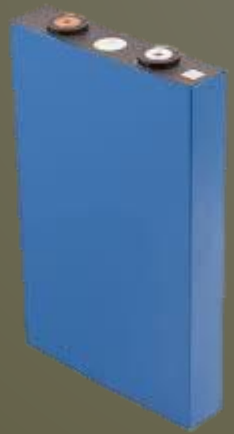
Lithium Battery Chemistry

What is different is that Lithium (Li) is volatile, it has an oxidizing (fire) reaction with H_2O (water). So, from construction Lithium Battery Cells are sealed, to prevent interaction with humidity 💧 causing Fire 🔥 …



Lithium Battery Chemistry

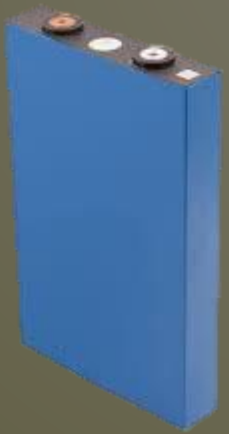
Now that we have Cells, they get wired together to become a battery. 4 in Series, and however many in parallel within each of the 4 Series connections to get to the desired Amp Rating. Then…



MINN KOTA

Lithium Battery Chemistry

LiFePO4 is the most stable commonly used Li Chemistry, the Li is chemically bonded preventing the fire risk even if a cell is punctured. Risks remain if you improperly charge or discharge the battery, so a key part of any Lithium Battery is a Battery Management System.



MINN KOTA

Lithium Battery Chemistry

The Battery Management System (BMS) is a “computer” that Monitors:

- Temperature (too high or too low)
- Cell Balance (charge level between cells)
- Discharge Rate
- Charge Rate

The BMS will Disconnect the battery from the Load or the Charger if an adverse environment or damage to the cells is detected.

“Drop-In” Batteries have an Internal BMS, some applications (your cell phone, laptop, i-Pilot Link remote, other electronics) the BMS will not be part of the battery pack but is certainly in use.

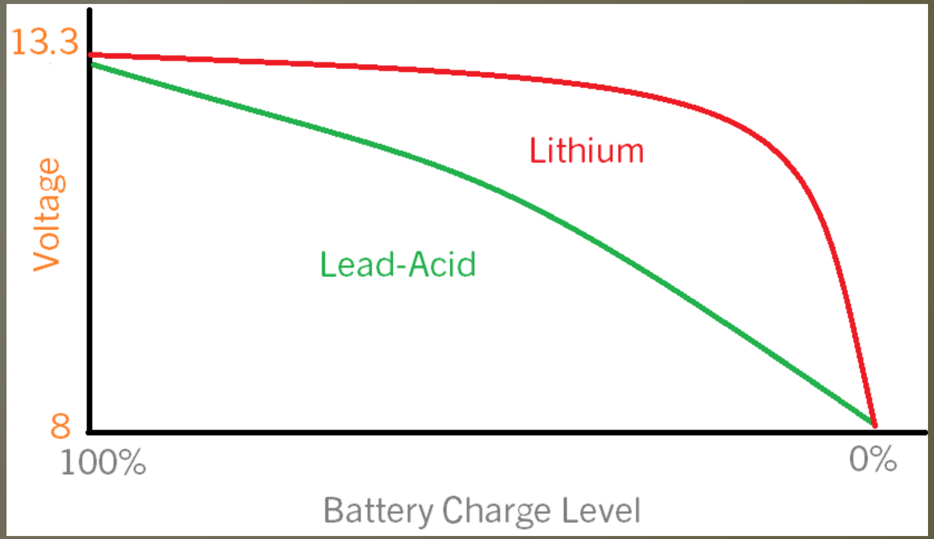
Lithium Battery Chemistry

The thing to know here is when you connect to a "Drop-in" Lithium Battery you are 'asking' the BMS to provide power from the actual battery, not connecting to the battery. If a Lithium Battery stops providing power, it is often because the BMS detected a fault and shut off.

Most BMS are turned back on by simply disconnecting all conductors from the terminal briefly, then reconnecting them.

Battery Comparison

Lithium Batteries start at a slightly higher voltage than Lead Acid and maintain a higher voltage for most of the discharge curve.



Many devices designed to operate on Lead Acid Batteries may need to be used differently when powered by Lithium Batteries to avoid damage to that device.

MINN KOTA

Boat Wiring

Philosophy

Conductor Gauge

Connections

Results

MINN KOTA

Philosophy

Electricity is the “life blood” of the Minn Kota electric fishing motor and if electricity is the “life blood” the “heart” of the Minn Kota motor is the battery. A battery (or batteries, in the case of 24 volt or 36 volt) are the intended power source for all Minn Kota motors.

Philosophy

If the battery is the "heart" and electricity is the "lifeblood", the conductor/wiring is the "circulatory system".

Just as a constricted artery or a blockage can cause problems for the human body, inadequate gauge wire or poor electrical connections can cause problems for a trolling motor

MINN KOTA

Conductor Gauge

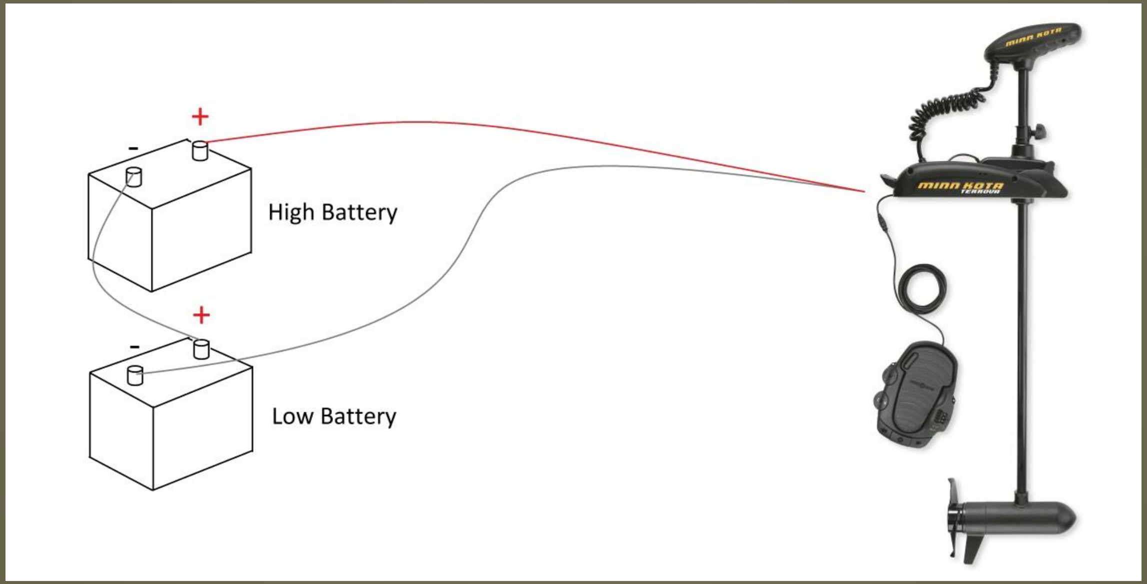
Voltage Loss/ Wiring Gauge Chart

Voltage lost per foot of conductor at the given Amp draw

AWG	5 Amps	10 Amps	20 Amps	30 Amps	40 Amps	50 Amps
4	.0012 v	.0025 v	.0050 v	.0075 v	.0100 v	.0125 v
6	.0020 v	.0040 v	.0080 v	.0120 v	.0160 v	.0200 v
8	.0032 v	.0064 v	.0128 v	.0192 v	.0256 v	.0320 v
10	.0051 v	.0102 v	.0204 v	.0306 v	.0408 v	.0510 v
12	.0081 v	.0162 v	.0324 v	.0486 v	.0648 v	.0810 v

Conductor Gauge

With a typical 24 volt rigging with 20’ from batteries to motor you have 40’ of total conductor (20’ of red plus 20’ of black wire).

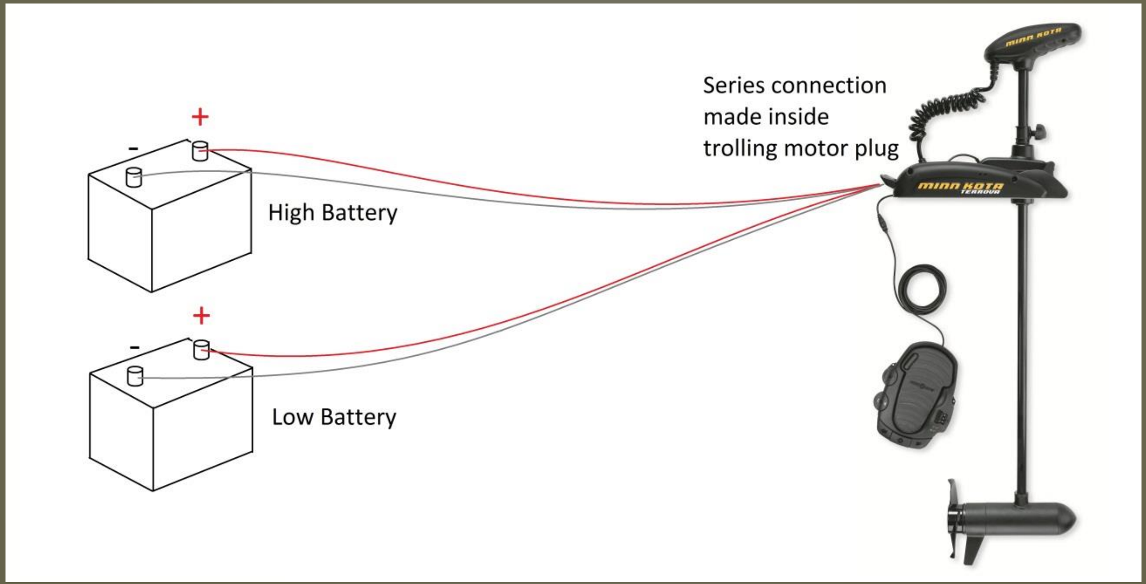


Using 8-gauge wire, 50 Amps causes .0320 v to be lost per foot, in this system you loose 1.28 volts (40’ x .0320) with 8 AWG wire

Using 10-gauge wire, 50 Amps causes .0510 v to be lost per foot, in this system you loose 2.04 volts (40’ x .0510) with 10 AWG wire

Conductor Gauge

A less common but occasionally used method of rigging runs 4 wires the length of the boat and makes the series connection at the trolling motor plug. In this example you have 80’ of total conductor



Using 8-gauge wire, 50 Amps causes .0320 v to be lost per foot, in this system you loose 2.54 volts (80’ x .0320) with 8 AWG wire

Using 10-gauge wire, 50 Amps causes .0510 v to be lost per foot, in this system you loose 4.08 volts (80’ x .0510) with 10 AWG wire

Connections

Electricity can efficiently move from one conductor to another through a connection that is clean and mechanically tight. Loose connections or ones that exhibit corrosion will be points of high resistance.

On the left is an example of good connections; assuming that they are tight. The corrosion on the example on the right causes increased resistance which will affect motor performance. Loose connections will also have a negative affect on performance.

MINN KOTA

Results

- Reduced performance
  - Voltage to the motor is reduced by bad connections, inadequate wire gauge, or bad batteries
  - Lower Voltage means slower operation
- Reduced Battery Life
  - Bad batteries have limited life
  - Running the motor at higher speeds to get the same performance consumes battery faster

MINN KOTA

Results

- Erratic Performance (Electric Steer Motors)
  - The “Logic” for a compass heading is an assigned voltage
    - If voltage to the motor drops after the voltage is assigned to a heading that voltage may not be possible, the motor will spin
  - Radio Receivers measure changes in an electric field, the stronger that field the better the reception.
    - Inadequate range on a remote can be caused by limited power getting to the motor.

MINN KOTA

Motor Theory

Electromagnetism

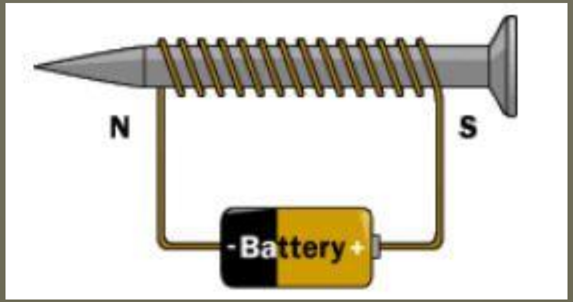
Commutation

Speed Variation

Brushless Motors

Electromagnetism

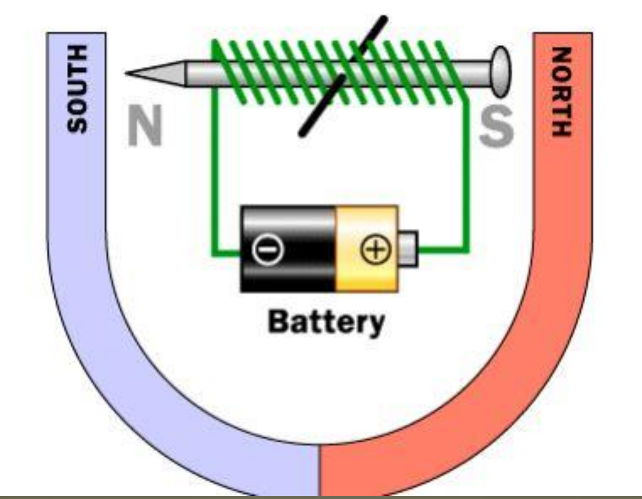
What happens when we wrap that conductor around an iron bar, connect one end to the anode and the other to the cathode?



A magnetic field is created through the iron bar.

Electromagnetism

The North and South poles of that Electromagnet are defined by the direction of the current Flow



Like magnetic poles repel each other, opposite magnetic poles are pulled toward each other.

This becomes the Basis for an Electric Motor

Commutation

To make an electromagnet into an electric motor put it inside of a magnetic field and then keep switching the direction of the current flowing through it.

MINN KOTA

Commutation

On all Minn Kota Motors the magnetic field is created by "permanent" magnets in the center section.

Commutation

The “Iron Bar” in the Electromagnet is the “stack” on the armature.

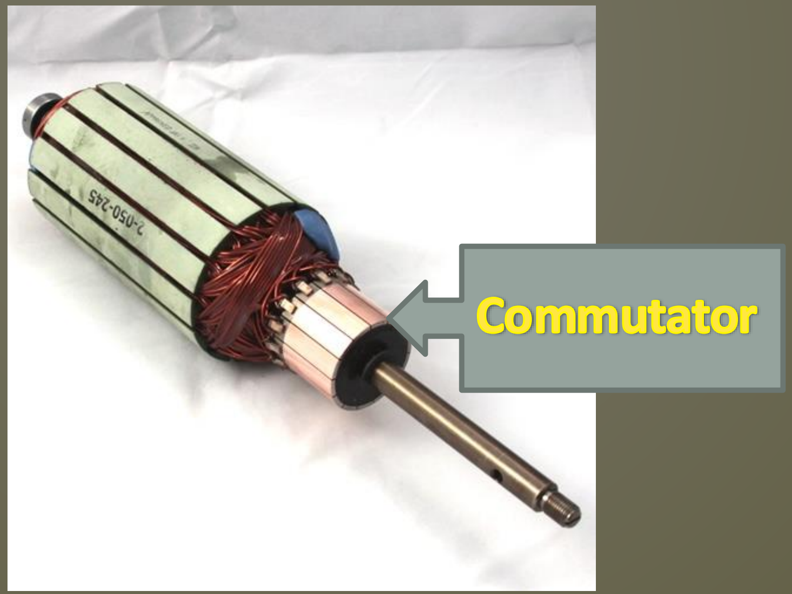
Commutation

Current is carried around the stack in the windings. Changing windings keeps the motor moving.

MINN KOTA

Commutation

As the armature rotates, where the Brushes contact the commutator changes, changing which windings are used.



Speed Variation

All else being equal, changing the voltage or effective voltage to the motor will change the speed it is turning at. The higher the voltage the faster it will run.

The described voltage of a motor is the maximum for that motor's lower unit; operating a 12v motor at 24v will make it run faster, until it burns up.

So speed variation is accomplished by reducing the voltage getting to the lower unit.

MINN KOTA

Speed Variation

There are two different methods of speed variation used in Minn Kota Motors:

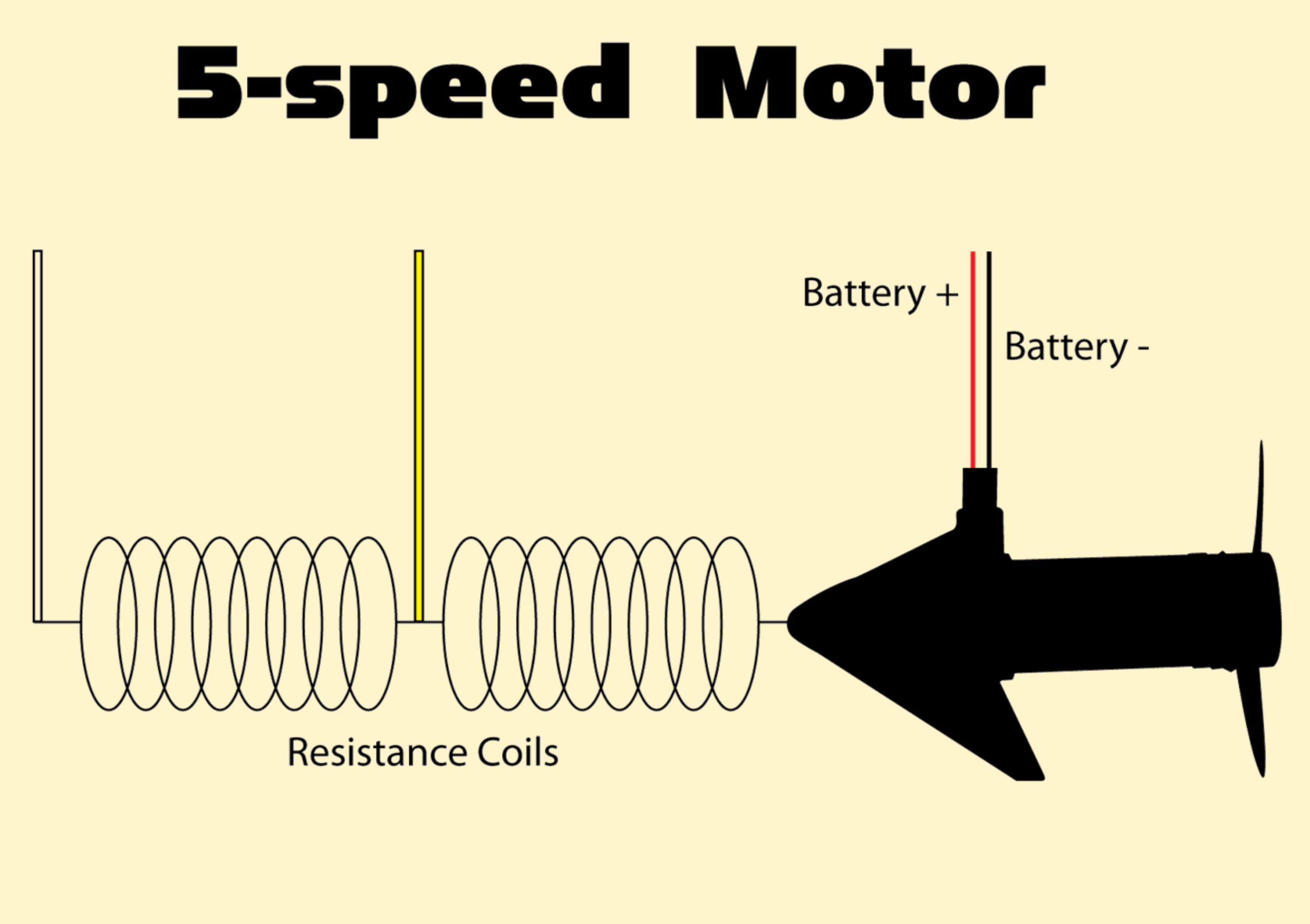
- 5 Speed motors have the voltage to the motor reduced using resistance or “speed” coils
- Variable speed motors use a control board with a Pulse Width Modulation circuit to reduce the effective voltage to the motor

Speed Variation

5 Speed Motors: Speed Coils (SC)

- If a resistor is wired in series with another item the resistor reduces the voltage on that circuit.
- This is an inexpensive method of speed variation
- Tapping the coil in multiple locations and then varying the route the current takes allows different speeds
- ✘ Offers a limited number of variations
- ✘ Inefficient; turns a significant portion of the available energy into heat

Speed Variation



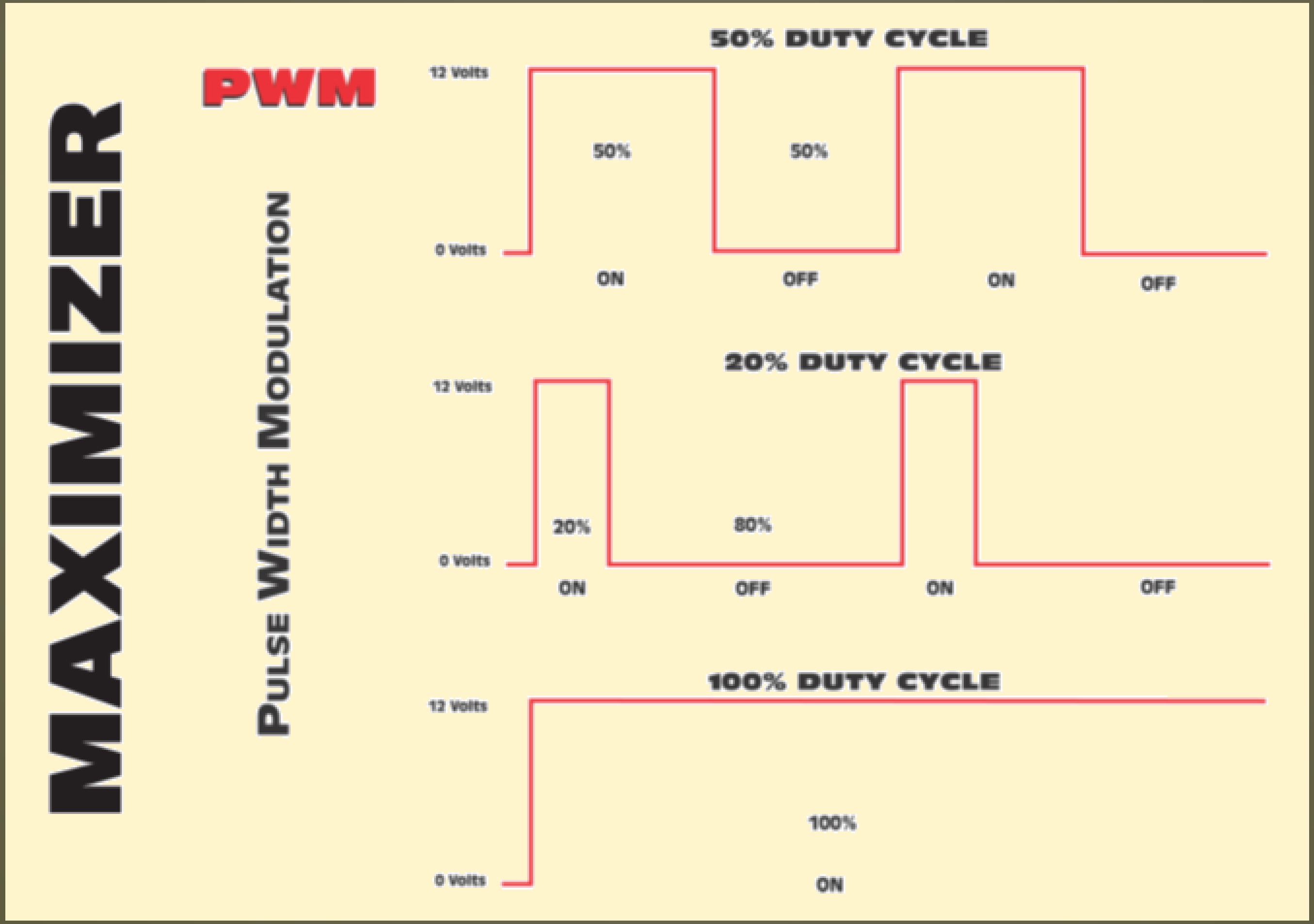
Speed Variation

Variable Speed Motors: Digital Maximizer

- Pulse width modulation (PWM) switches on/off very rapidly (thousands of cycles per second)
- Controller input varies the number of “on” cycles
- Higher percentage of “on” cycles creates an effective voltage closer to the input voltage
- Allows for an infinite variation of speeds
- Runs very efficiently, very little energy lost as heat
- ✘ More expensive than speed coils

MINN KOTA

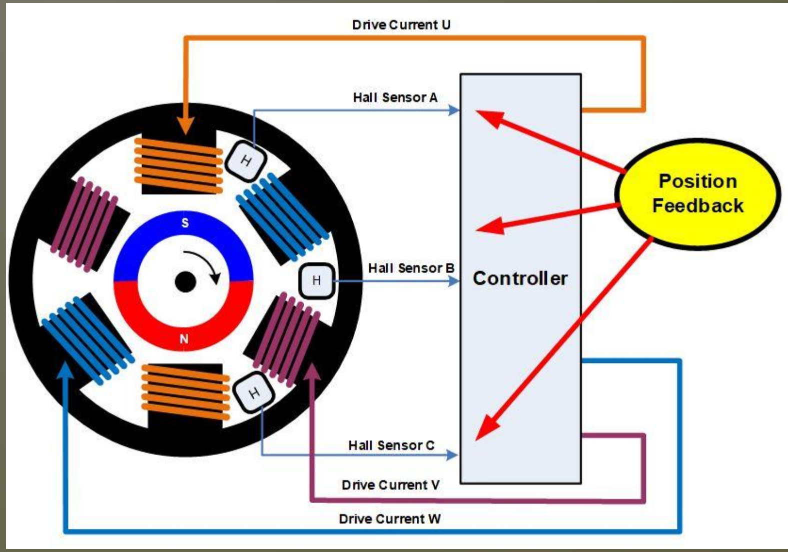
Speed Variation



MINN KOTA

Brushless Motors

Where a permanent magnet brushed motor uses brushes/commutation to mechanically switch the location of the electromagnet relative to the permanent magnet a brushless motor uses a control board to electronically switch the location of the electromagnet. Typically for the same function this means swapping the location of the electromagnet and permanent magnet, a trolling motor would most likely have a permanent magnet rotor with the windings in the housing surrounding the rotor.



MINN KOTA

Brushless Motors

PM Motor:

- Arcing at Brushes creates RF
- Speed controlled by limiting voltage to the brushes, slowing the motor as desired
- Brushes wear out over time?
    - Brush life on Minn Kota motors exceeds most use cases
- Significantly Less Expensive.
- More serviceable

Brushless Motor:

- Controller Switches without arcing
- Speed precisely and efficiently controlled via position sensing and electronic control
- No wear components
- Distance from the Rotor to the outside of the motor allows for a more powerful magnet to be used.
- More Expensive to produce and service.