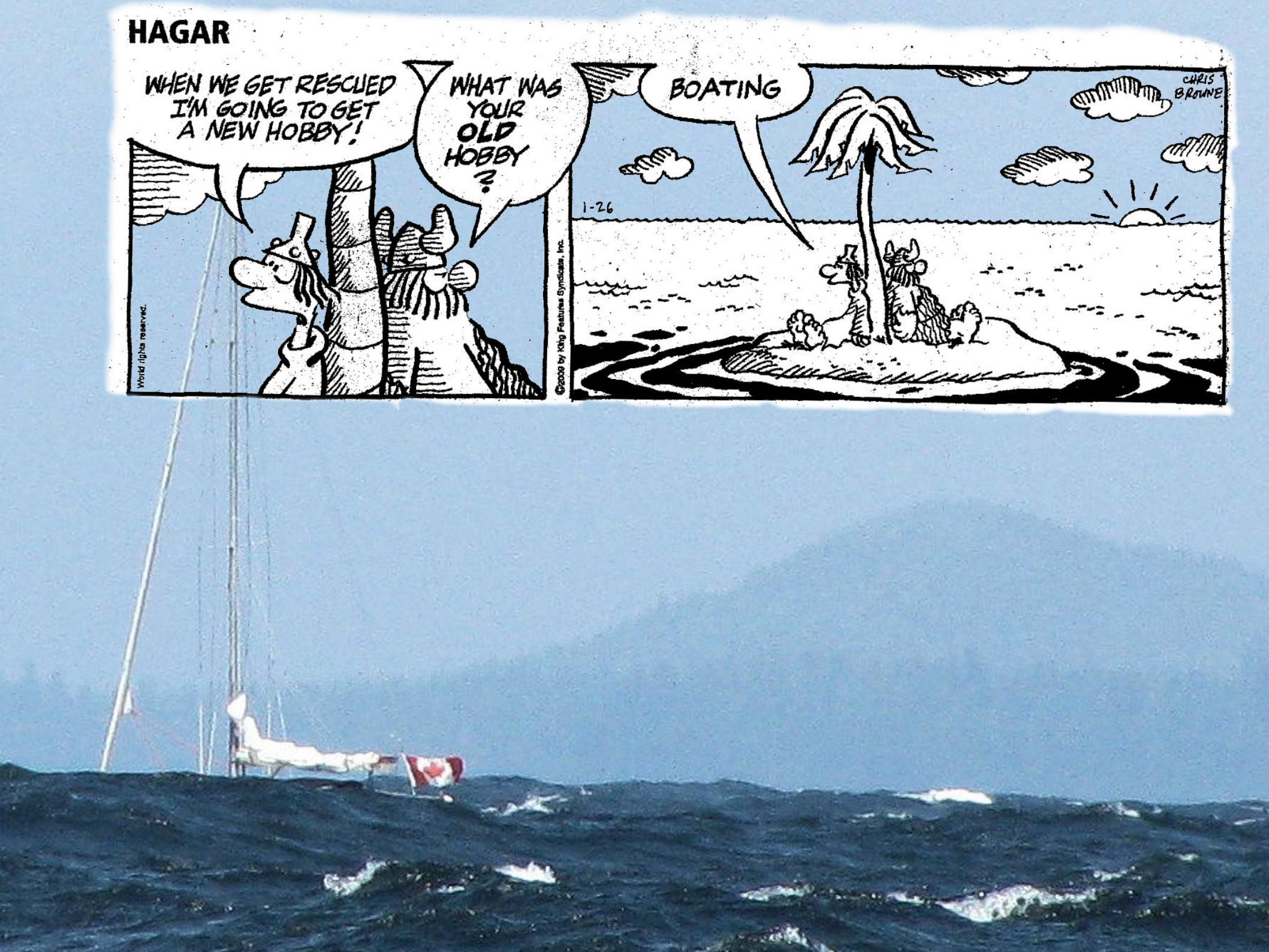
HAGAR
WHEN WE GET RESCUED I'M GOING TO GET A NEW HOBBY!
WHAT WAS YOUR OLD HOBBY?
BOATING
CHRIS BROWNE
1-26
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Major Components

- Alternators
- Powering your Laptop / Portable Electronics
- Battery Selector Switch and Isolators
- Data connections between Instruments
- Radio connections
- ESD safety

Alternators

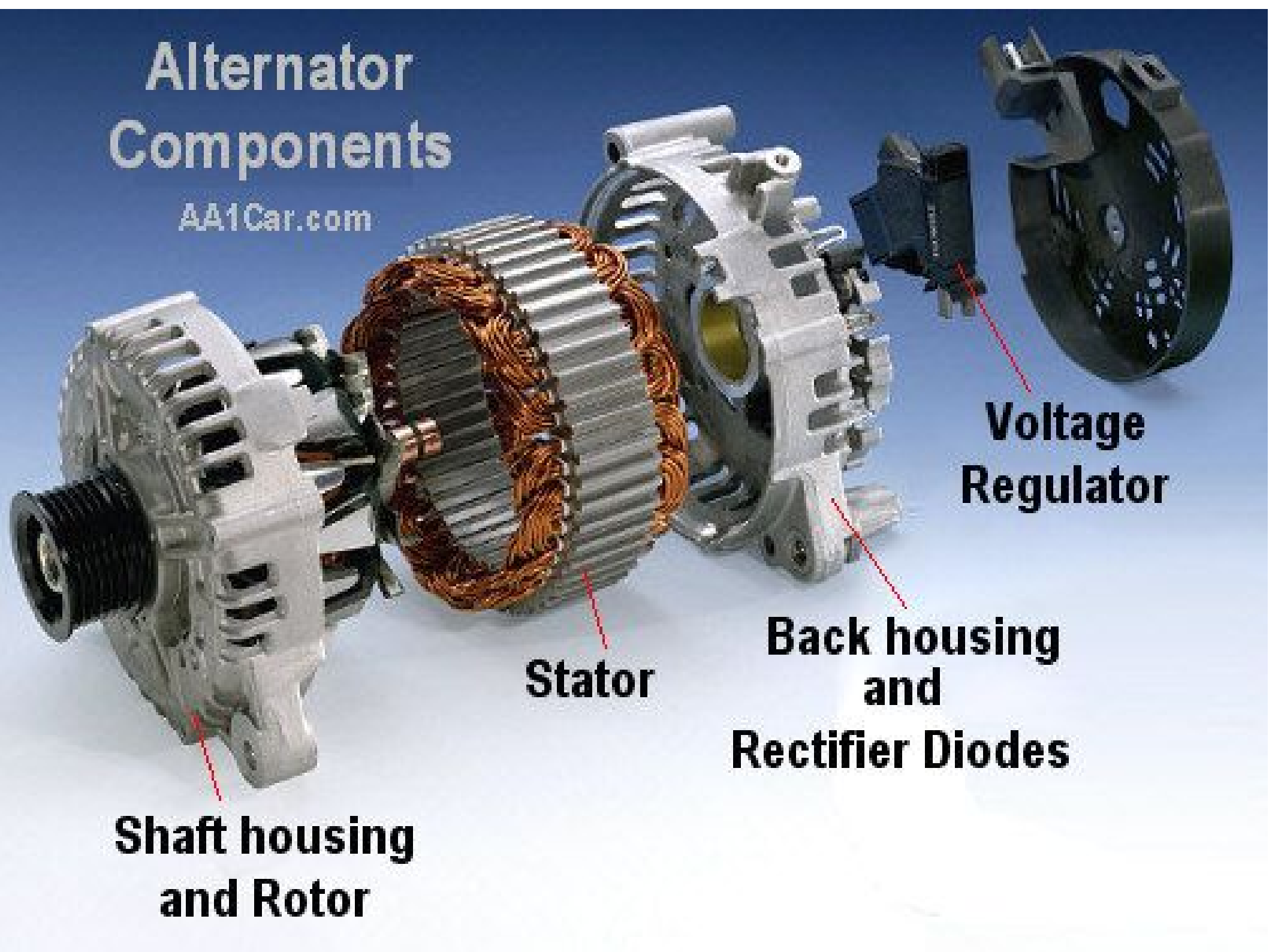
- Enemy is **HEAT**
  - bad for bearings, diodes, belt
- Care for yours by:

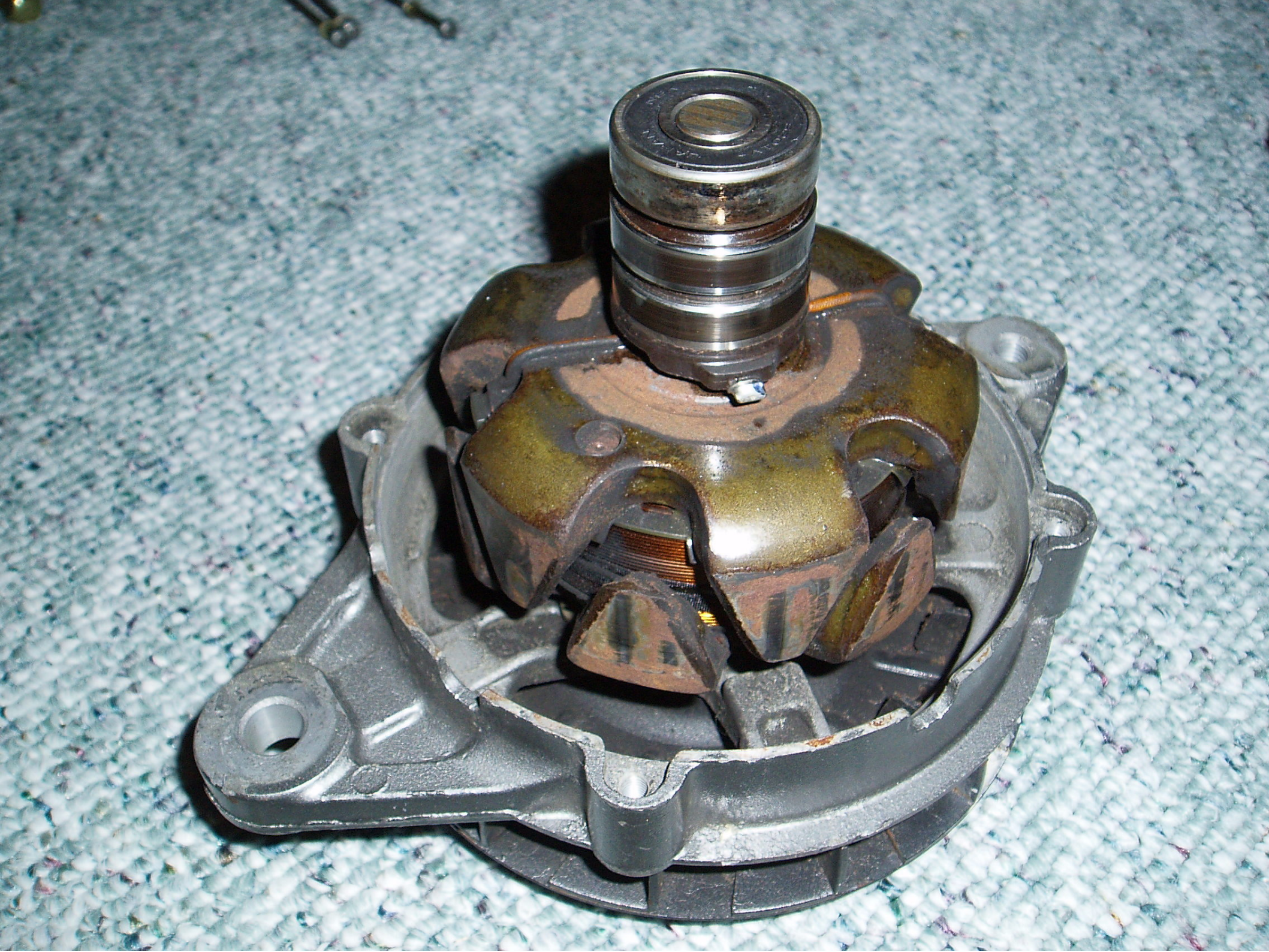
  - checking belt tension, removing dust/dirt, and ensuring good supply of cooling air
- Worthwhile Improvements

  - toothed (castellated) belts

  - generous-sized cables from alternator to battery positive and negative (don't rely on engine chassis for grounding)

  - external multi-stage battery charge regulator


Alternator
Components
AA1Car.com
Voltage
Regulator
Stator
Back housing
and
Rectifier Diodes
Shaft housing
and Rotor



Bad Alternator

- Your battery will **fail to charge** while motor is running, or
- (less often) the battery is **overcharged** to too high a voltage

- Best way to notice a problem is to install a battery monitor

Bad Alternator

Low or zero Alternator output (dead battery)

caused by:

- Slipping/broken drive belt
- Loose/corroded connections
- Defective diode(s), or
- Defective voltage regulator.

First two problems can be discovered by inspection.

Defective diodes or voltage regulator can be diagnosed with voltmeter

Bad Alternator

Too High Alternator voltage (overcharged battery)

symptoms:

- low battery electrolyte,
- damaged battery plates from overheating, or
- burned out bulbs & electronics.

caused by:

- Defective voltage regulator, or
- Poor regulator-to-ground connection.

Confirm with a voltmeter: when charging properly, voltage should read no higher than about 14.7 V, depending on temperature, battery type, charging mode

Bad Alternator

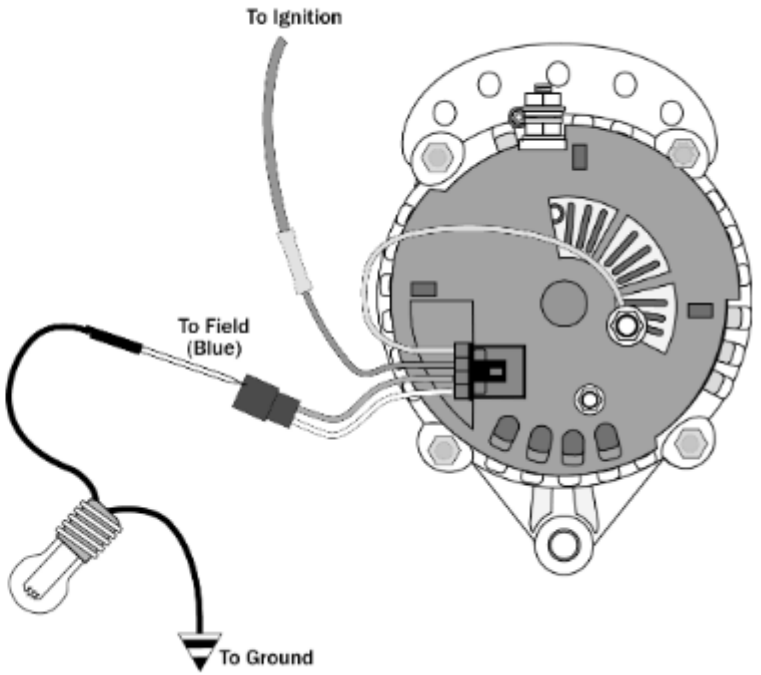
- To **troubleshoot**, download a service manual for your alternator (or a similar model). It's not too complicated – you just need to be able to **make voltage, current, and resistance measurements**.

e.g. from Balmar alternator manual:

SMART READY® REGULATOR TEST

Six-Series alternators require slightly different diagnosis to determine if the Smart Ready® internal regulator is functioning correctly. To test the internal regulator:

1. Disconnect the external regulator wiring harness from the alternator wiring plug containing the field and stator wires. Turn the ignition switch to the ON position.
2. Contact the positive probe of your test lamp on the FIELD terminal of the wiring plug. Connect the tester's negative probe to ground. If the internal regulator is functioning properly, the test light will illuminate.
3. If testing the operation of the internal regulator with a multimeter, adjust the meter to read DC volts before placing probes at the field terminal and ground. If the regulator is working correctly, the meter will show approximately 3V DC.



Alternators & Lithium Batteries

If you replace your lead-acids with lithium batteries, you may also need to **upgrade your alternator**.

- the much higher charging rate of a lithium battery will overheat your alternator if it isn't rated for the higher current
- check also that the charging and float voltages of the alternator's regulator are suitable for your battery(ies)


Mobula Ray

Laptop & Handheld Charging

- Keeping your electronics running requires an assortment of voltages: 5 V (USB), 19 V (laptops).
- Your boat likely has a 12 or 24 V battery system, and may also have 115 VAC from an inverter
- Electricity is precious – how can you make the best use of what you have?

Laptop & Handheld Charging

Avoid converting your 12 VDC to 115 VAC and then back to 19 VDC.

If each conversion is 85% efficient,
then for each 10 Amp-hours your laptop draws, your battery needs to supply 14 A-hr.

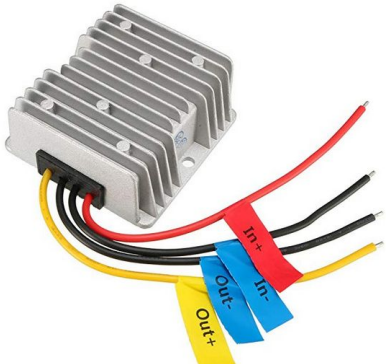
12 V

120 V

19 V

With only one conversion, each 10 A-hr requires 11.5 A-hr from the battery.

12 V



19 V

Laptop & Handheld Charging

- Check your laptop's supply voltage, and max current draw.
- Get a converter that supplies that voltage (+/- 5%) and at least 50% more current (for reliability)

amazon

uxcell Power Converter Regulator DC12V(10V~16V) Step-Up to DC19V 6A 114W Waterproof Voltage Convert Transformer

by uxcell

15 customer reviews | 9 answered questions

Price: $18.99 + $9.59 Shipping & Import Fees Deposit to Canada Details

Your cost could be $13.99. Eligible customers get a $5 bonus when reloading $100.

Size: **12V to 19V 6A 114W**

12V to 19V 6A 114W $18.99	12V to 19V 8A 152W $19.99
12V to 19V 15A 285W $29.99	12V to 19V 20A 380W $38.99
24V to 19V 5A 95W $16.99	

- Waterproof IP68 Voltage Converter Regulator DC 12V to DC 19V 6A 114W.
- Protections: Over-load, Over-current, Over-temperature, Short-circuit, Over-voltage.
- Auto-recovery when device is back to normal operating; high transfer efficiency of 96% max..
- Die-cast aluminum shell, anti-shock, and moisture-proof and has stronger durability.

Laptop & Handheld Charging

- Similarly, for handheld devices that need 5 V, use a 12 V to 5 V converter. Avoid AC-powered adapters that need you to run your inverter.

Accessory Outlets

12 V accessory outlets have limitations:

- Original design was as a cigarette lighter
  - Temporary connection: ***low pull-out force***
  - Intended to heat up: ***higher resistance***
  - Point-contact spring plunger: ***limited to ~10 A***

Accessory Outlets: Better Options

dedicated USB (5V) outlet

- ***Avoids unreliable 12V cigarette lighter outlet***
- ***Compact***
- ***Designed for ~1500 connect/disconnect cycles***

12V Accessories

Anderson Power Pole connectors

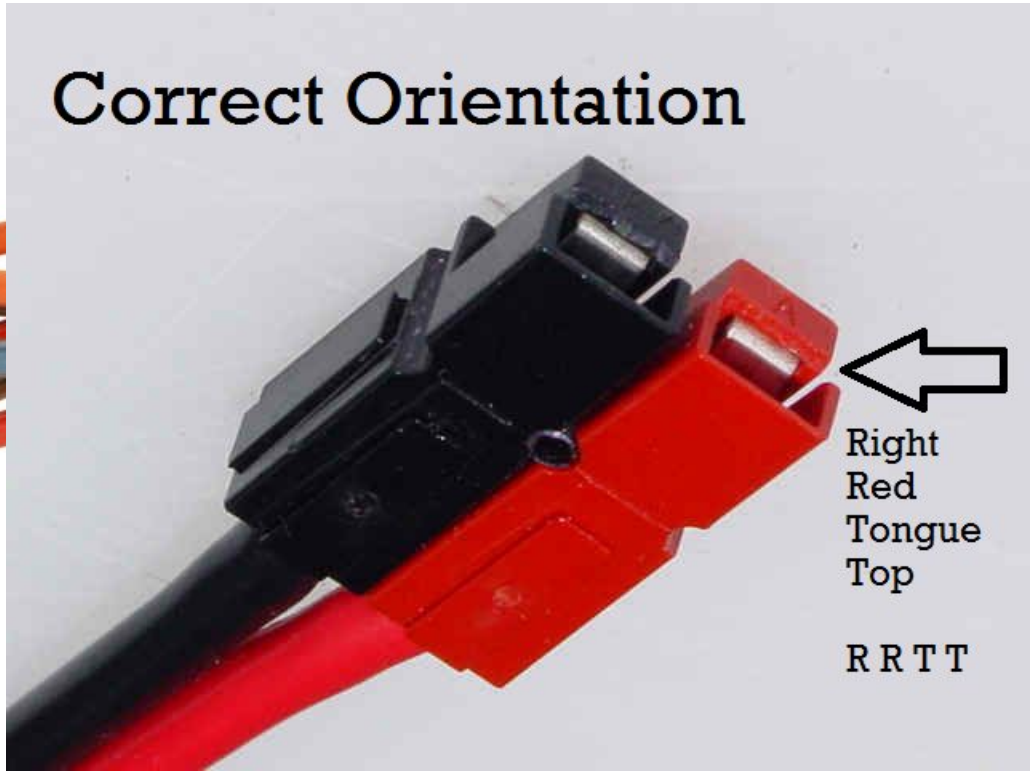
- Common size is rated for 15 / 30 / 45 A
- Designed for 100,000 connect/disconnect cycles (no-load)

12V Accessories

Anderson Power Pole connectors

- Available in various colours
- Housings can be stacked in different configurations

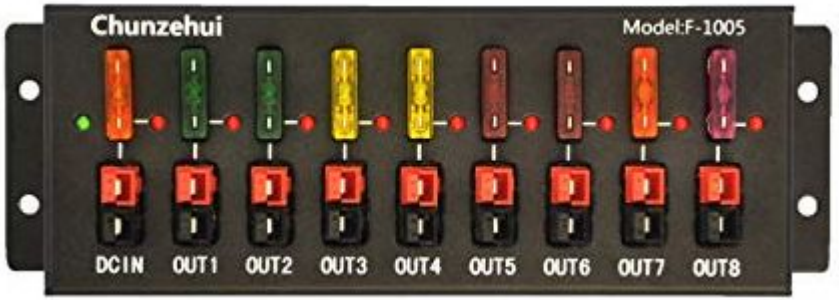
Amateur Radio convention – most common



12V Accessories

Anderson Power Pole connectors

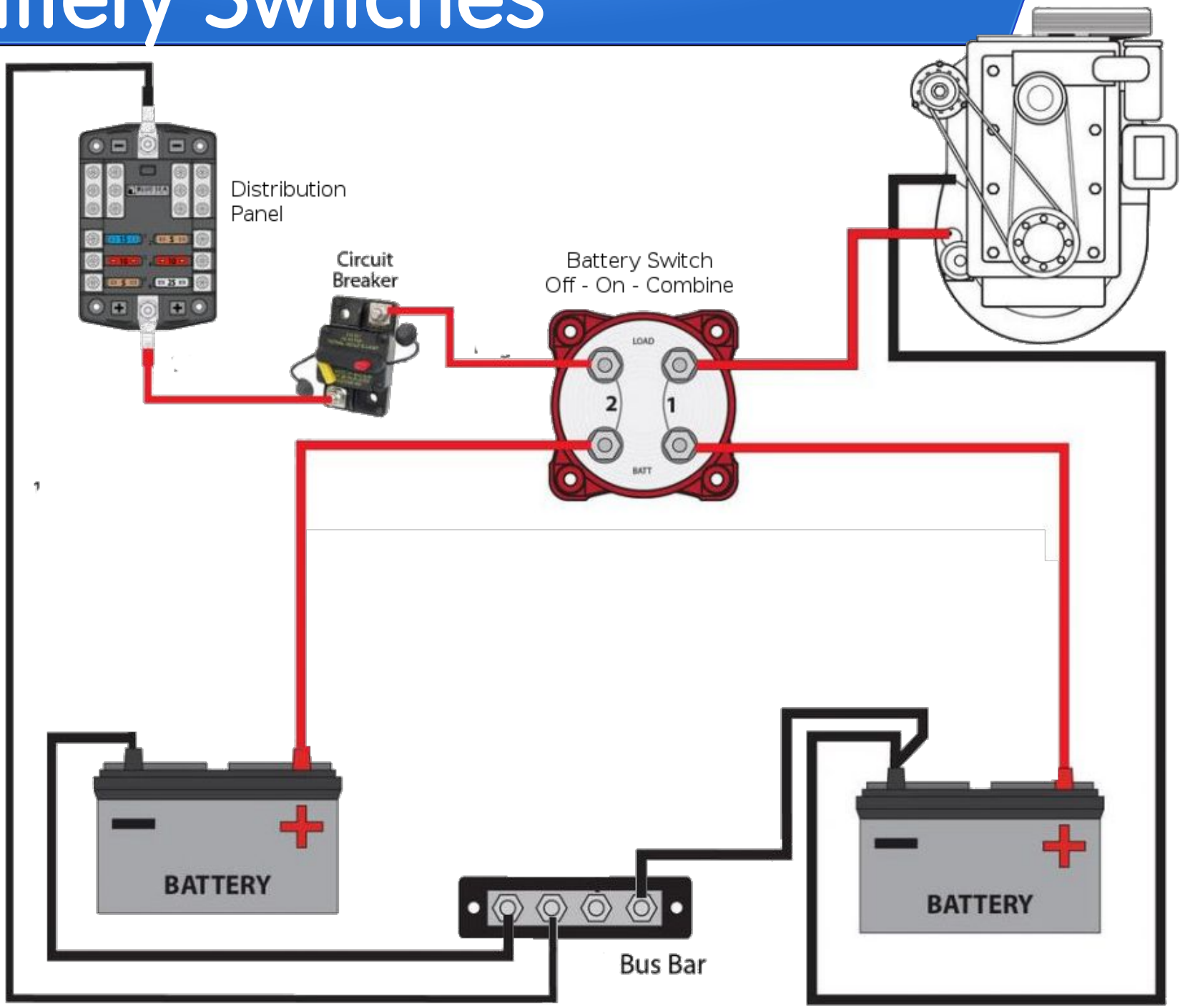
- Crimpers, Contacts, and distribution panels are available on Amazon




Pacific White-sided Dolphins

Battery Switches

Battery Switches



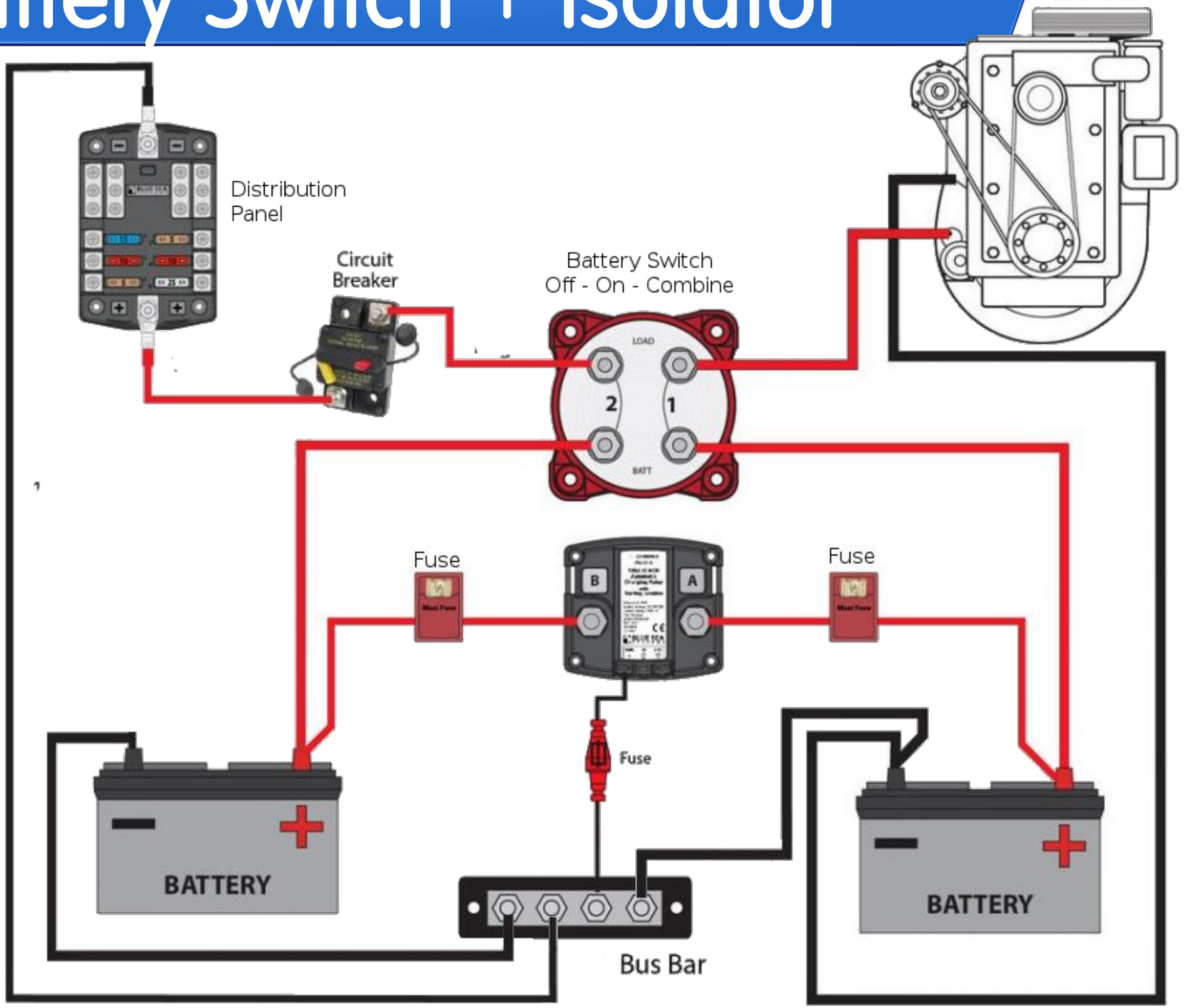
Battery Isolators

Charge both batteries, without needing battery switch set to “BOTH”

When one battery is being used (e.g. house bank), prevents second battery from also draining.

Both batteries need to be of the same chemistry (so charging voltage is appropriate for both).

Battery Switch + Isolator




Ornate Bella Moth

Data Connections

Data connections on vessels usually follow one or more of these standards:

- **NMEA 0183** (two-wire serial)
- **NMEA 2000** (based on CAN-bus)
- **NMEA OneNet** (based on Ethernet and IPv6)
- **SeaTalk** (Raymarine proprietary)
- **Ethernet** (some radars & other high-bandwidth devices)
- **Bluetooth** (wireless wind instruments, stereos, etc)

NMEA standards

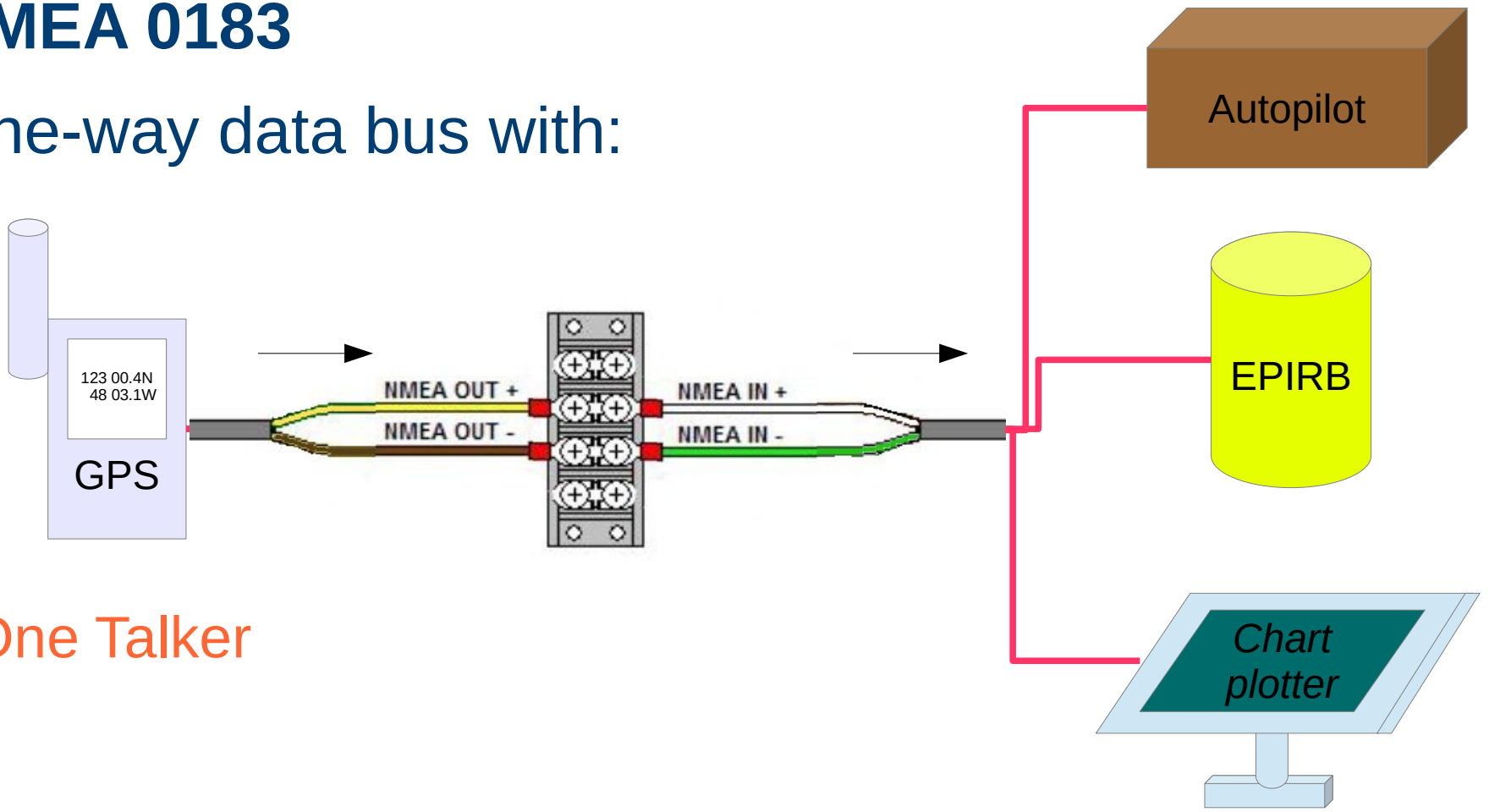
- *National Marine Electronics Association* publishes standards for connecting marine electronics.
- **NMEA 0183** describes a bus with **One Talker and Multiple Listeners.** It is quite slow (4800 bits-per-second or 38 400 bps)
- **NMEA 2000** describes a higher speed bus (50X faster than 0183) with **Multiple Talkers and Multiple Listeners**, used for higher-bandwidth data (e.g. radar, nav charts). The bus also provides power to connected devices. It isn't fast enough for live video.
- **NMEA OneNet** is based on Ethernet and Internet Protocol (IP). Just released in 2020, it will handle video and other very high bandwidth applications. Security is one of the key design goals.

Check www.nmea.org for more details.

NMEA 0183

NMEA 0183

One-way data bus with:



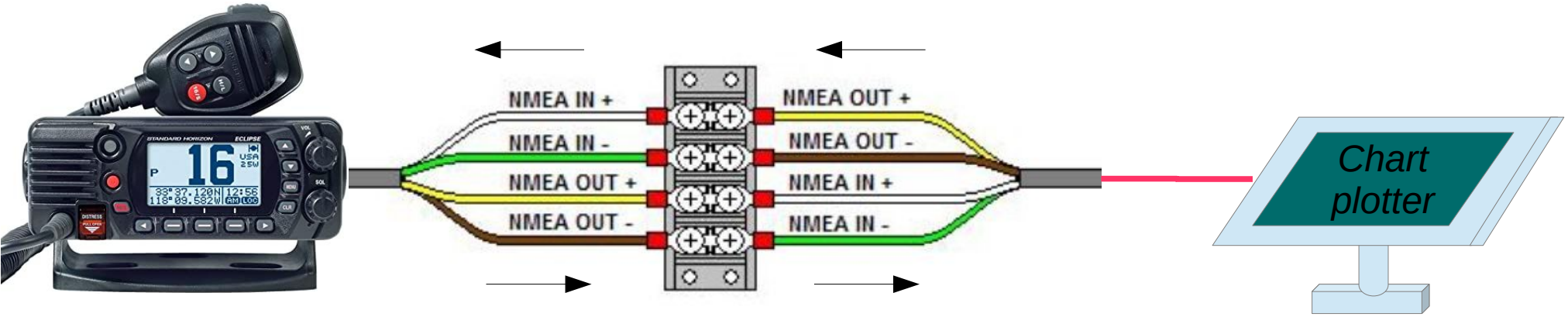
One Talker

Multiple Listeners

NMEA 0183

NMEA 0183

One-way data bus: needs 2 wire pairs for two-way data

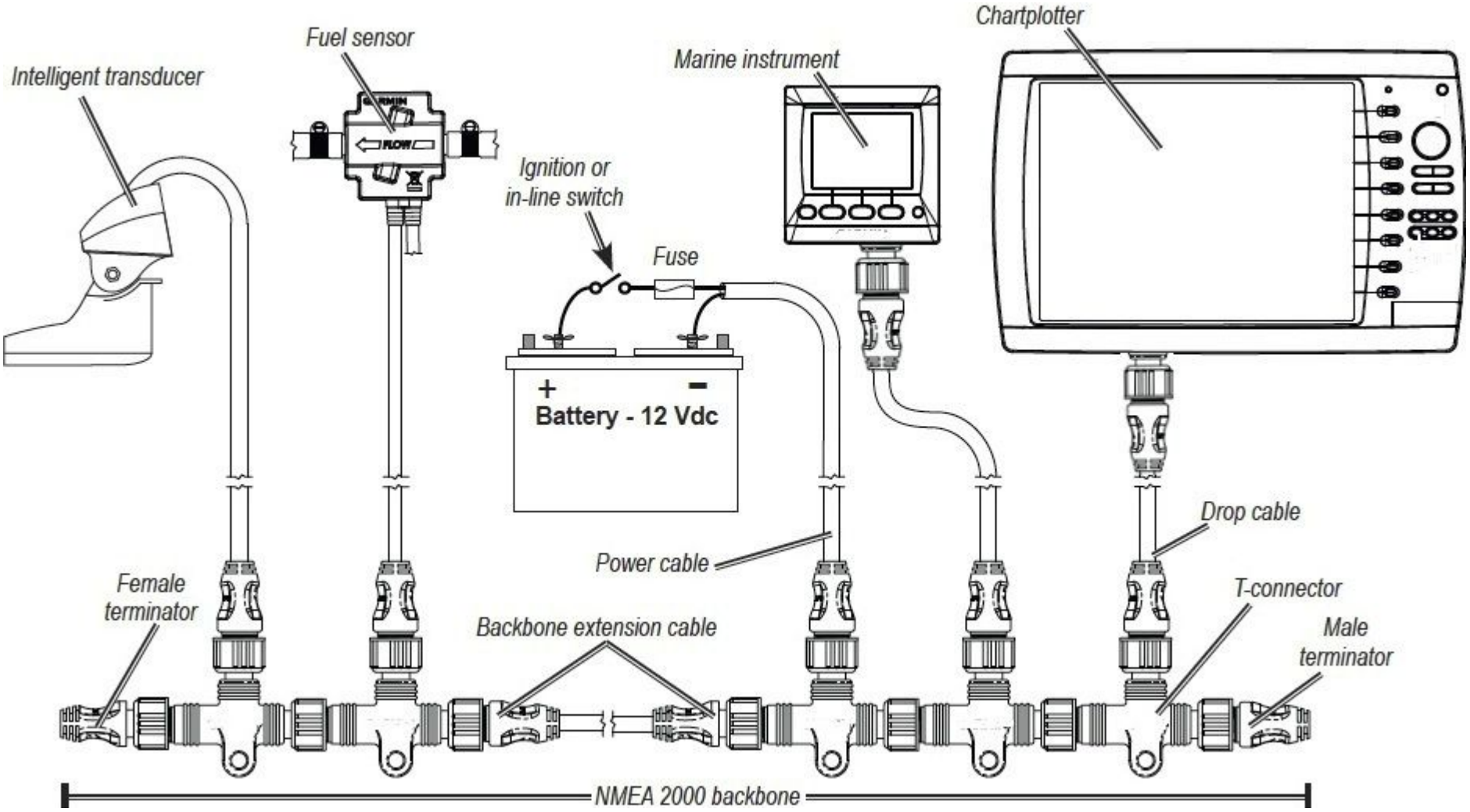


One Talker → One Listener

One Listener → One Talker

NMEA 2000

Medium-bandwidth two-way communications between multiple instruments

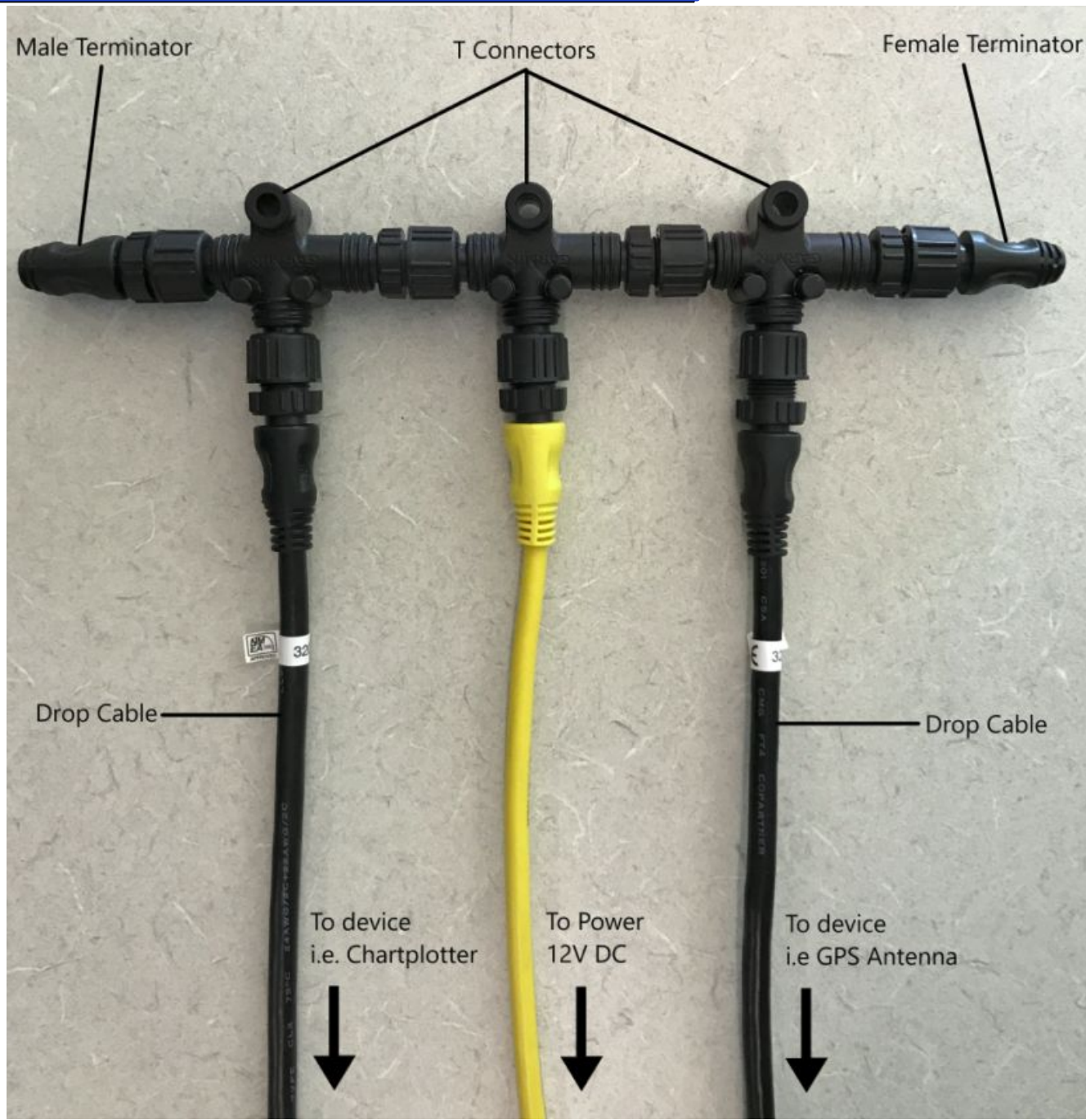


NMEA 2000

Components:

- Terminators
- Backbone
- Tees
- Drop Cable

Backbone carries both Signals and Power



NMEA 2000

Advantages over NMEA-0183

- Connectors are easy to use. Can be “hot-plugged” without damage.
- Multiple devices act as listeners and talkers
- “Auto-configuration” allows many devices to be recognized without complicated set-up
- Higher bandwidth supports autopilot, AIS, engine management, etc simultaneously
- Modest power (up to 1 A) from backbone

NMEA 2000

Challenges

- Older boats won’t have a factory-installed backbone.
- Not fast enough for video (e.g. security cams)
- Interoperability between brands isn’t 100% guaranteed


Eagle Ray

Radio Cable

Radio Frequencies (RF) require a different type of wire, called **Co-axial** (Coax) **Cable**

- See sample board. Common sizes used are ***RG-213/U, RG-8/U, RG-8X, RG-58/U, CA-195R***
- Thicker cables generally have lower losses. With regular wire, we talk about voltage drop – with RF, **losses are measured in dB.** 3 dB loss -> ½ power
- Don’t mix up coax intended for TV use (75 ohm) with that for **Ham/Marine HF SSB and VHF (50 ohm)**

Coax Connectors

PL-259 mating with SO-239

SO-239

- Robust, low-loss connector. Common on VHF and HF radios.
- Available for all common coax sizes

PL-259

- $5 each for good quality:
  silver-plated brass is better than *nickel-plated steel* as it solders easily and won't rust

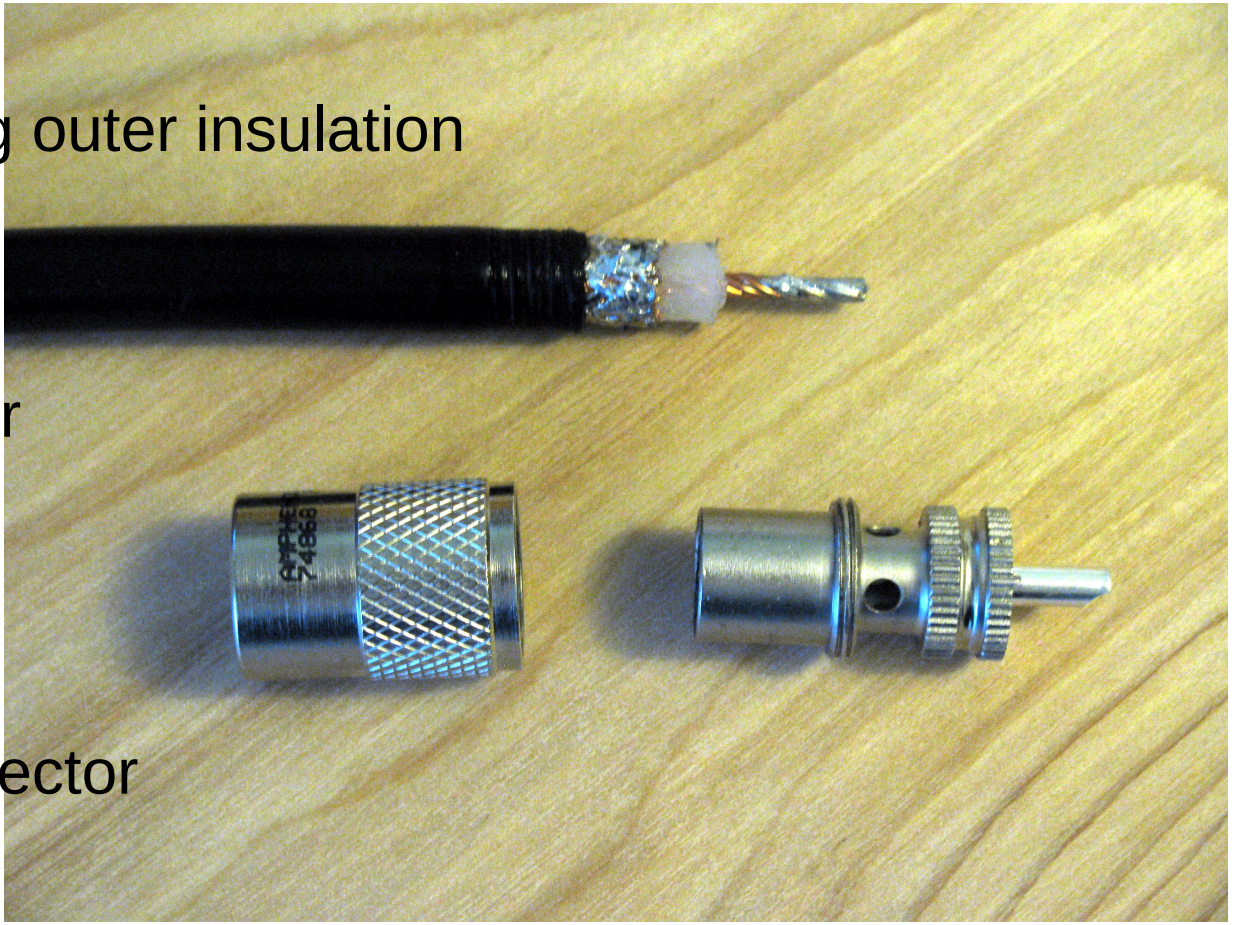
Assembling PL-259

Lots of descriptions on the web. A good one:

www.hcarc.us/articles/soldering%20PL-259%20connectors.htm

Basically:

- Slide collar on to wire
- Prepare wire by stripping outer insulation
- Tin copper braid
- Trim to length
- Thread connector on
- Solder braid to connector
- Check continuity
- Solder center conductor
- Trim center conductor
- Check continuity
- Thread collar on to connector



Coax Connectors

BNC

- generally seen on **lower-power** radio connections like AIS receiver
- Usually assembled by **crimping**. Solder versions available but I find them finicky to assemble.
- Not available for large-diameter coax like RG-213/U

RF Connections - Ground

Use wide copper foil strips where possible.

Tinned-copper braid is good where flex is needed.

Avoid skinny wires.

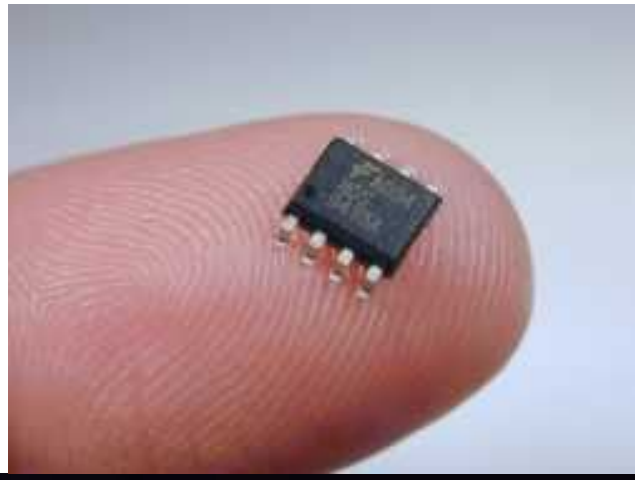

Turkey Vultures

ESD Safety

- ESD: Electrostatic Discharge

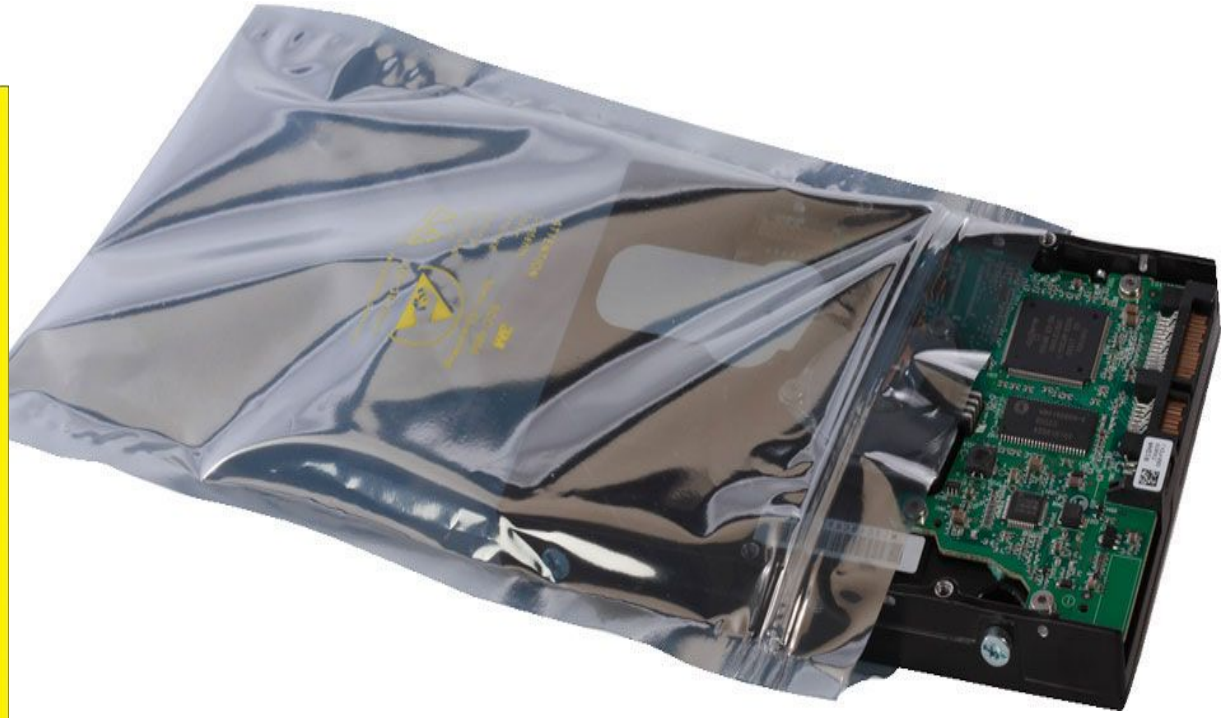
Electronic components can be **damaged by** a static discharge of as little as a **few hundred volts**

Your motion, and the rubbing of clothes, can generate static charges of thousands of volts



ESD Safety

- *Warning Symbols* indicate ESD sensitivity
- Electronic components are most vulnerable before installation; once mounted on circuit board they are better protected, but not immune.



ESD Safety

- Keep electronics enclosed in **factory shipping materials** (e.g. ESD-proof bags, non-static generating foam, etc) until ready to install.
- Install following **manufacturer's instructions** regarding ESD safety.
- **Avoid touching** exposed contacts and circuit boards with tools or your skin. Before picking up electronics, remove any static charge you have accumulated by touching a grounded conductor.

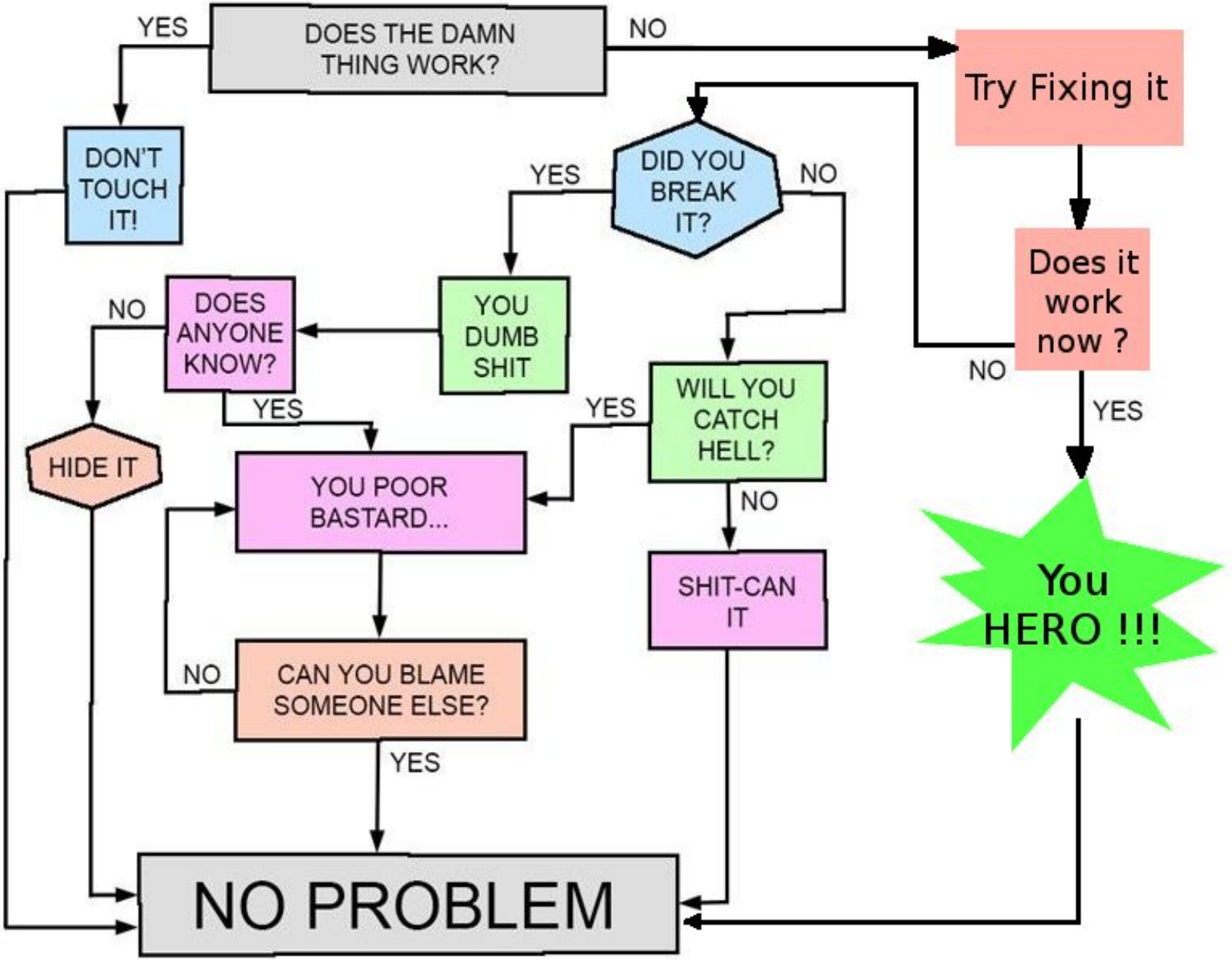
Major Components

We reviewed: *Alternators, Low-voltage DC converters, Battery Switches/Isolators, Data Connections, Radio Connections, and ESD Safety.*

Any Questions?

Troubleshooting

Troubleshooting



Troubleshooting

Were there any **warning signs**? Check for unexpected:

- ***sounds***
- ***smells***
- ***smoke***
- ***heat***

poor connections -> high resistance -> heat

Use all your senses to narrow down *where* the problem is.

Troubleshooting

Do you have a **substitute** you can try?

- try a new light bulb
- if a socket isn't delivering power, plug in known-good device

If the substitute works, chances are good you've found the problem. However, just to be certain, restore the original part and check again. *Why?* Sometimes bad connections are the true problem, and physically unplugging/loosening a connection will cause the device to work.

Be aware of double-fault problems (multiple failures).

Troubleshooting

If previous steps don’t find the problem, then **follow the path of the electricity** all the way from the battery to the part. Aim is to locate where the electricity stops.

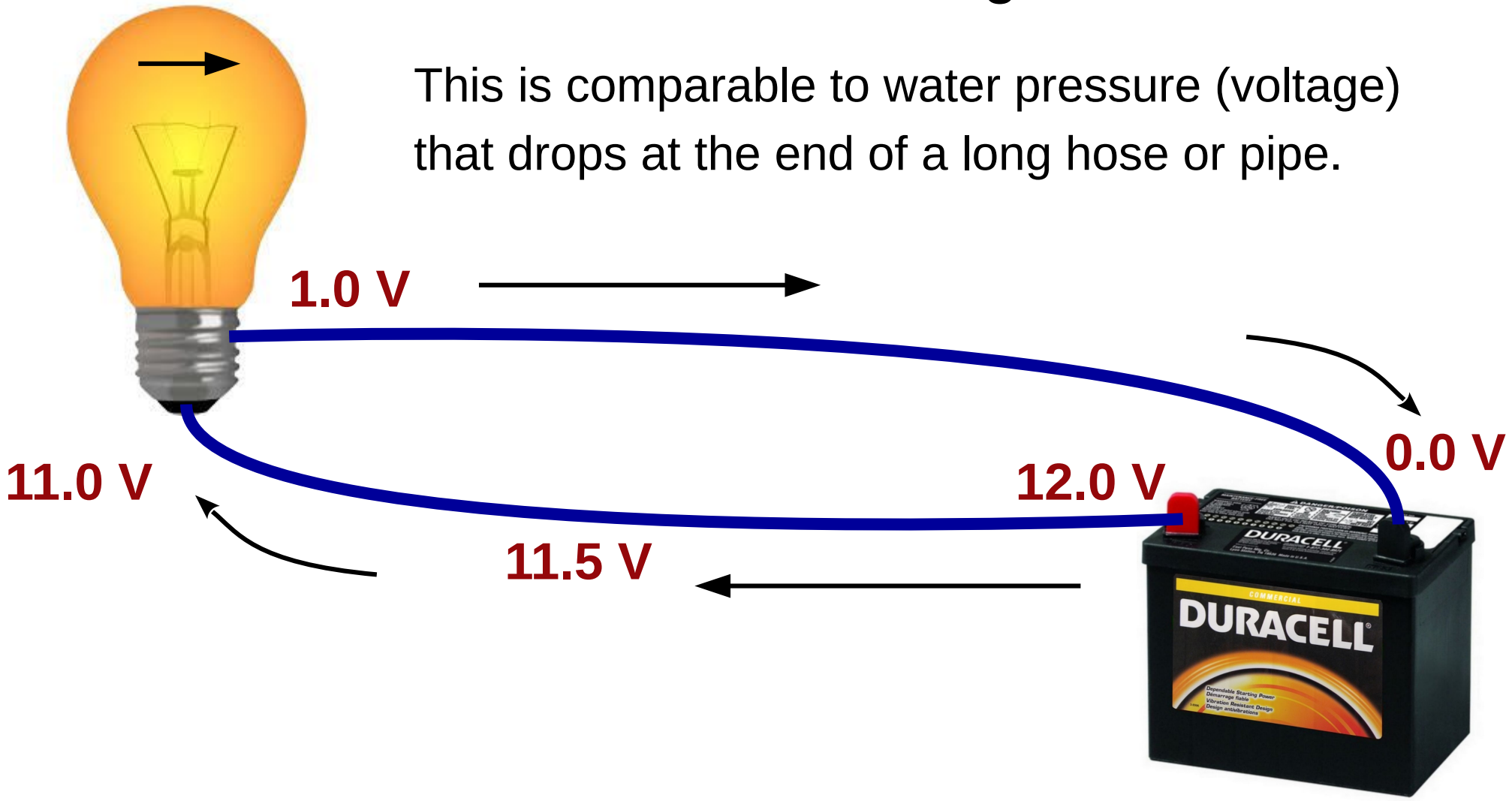
- Use meter to probe for voltage to device
- Try the most convenient test points first. Use existing terminals and connections: cutting wires is a *last resort.*
- Divide and conquer.

Troubleshooting

$$V = I \times R$$

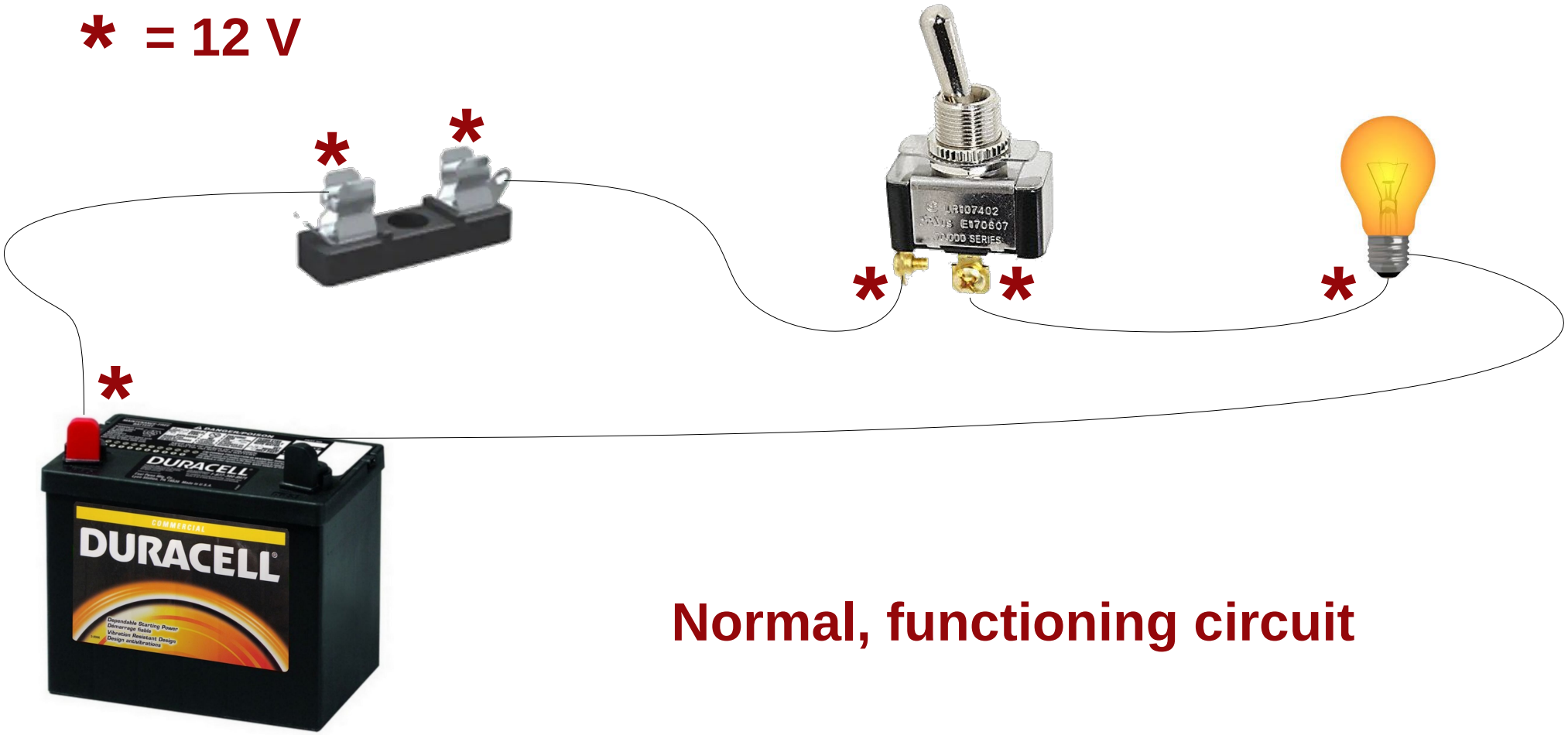
As current flows in a wire that has resistance, the voltage decreases.

This is comparable to water pressure (voltage) that drops at the end of a long hose or pipe.



Troubleshooting

Each point, up to the load/device, should read approximately = supply voltage.

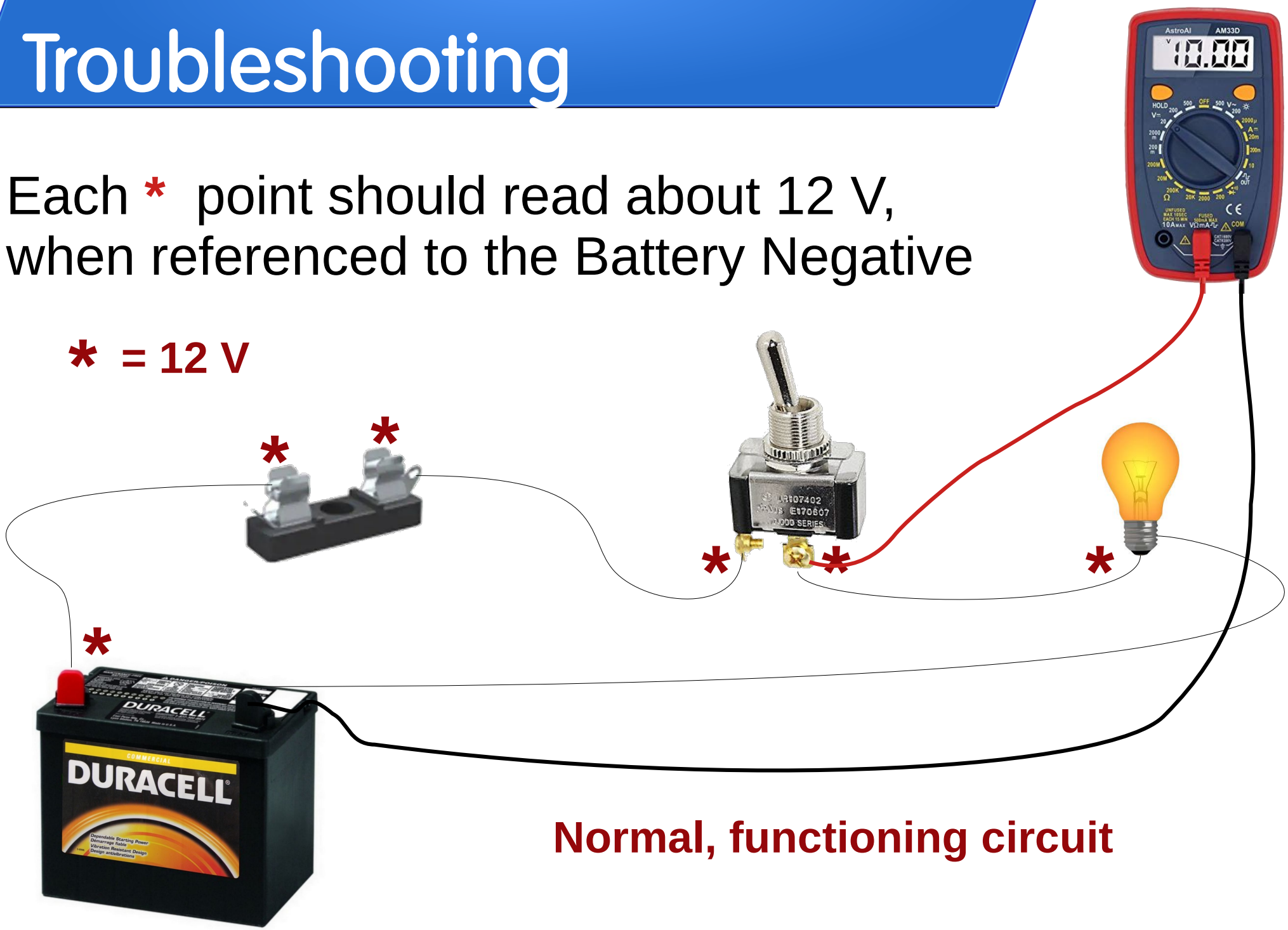


Normal, functioning circuit

Troubleshooting

Each * point should read about 12 V, when referenced to the Battery Negative

* = 12 V



Normal, functioning circuit

Troubleshooting

After load (downstream, or towards negative terminal), should read approximately = zero.

*** = 0 V**

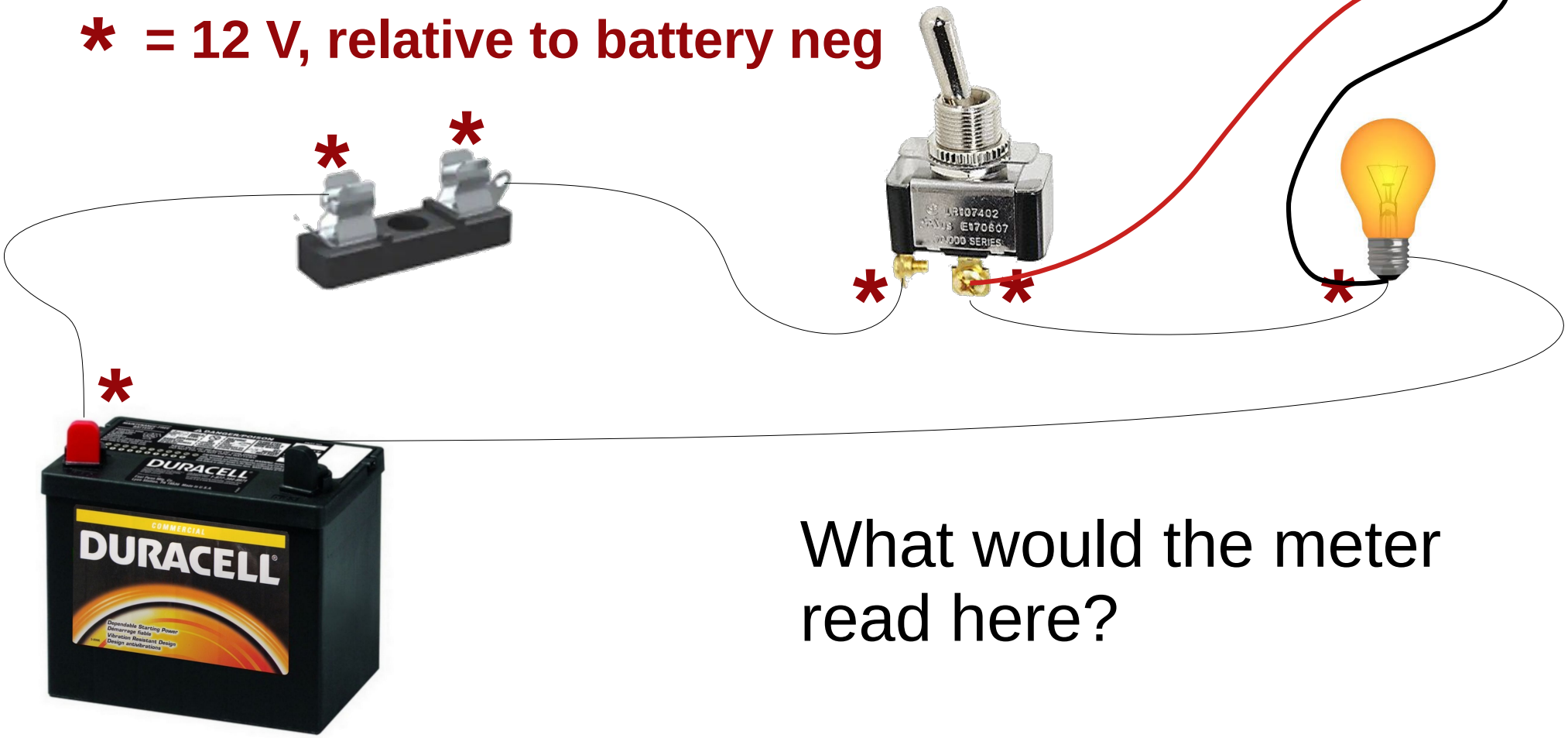
*****

Normal, functioning circuit

Troubleshooting

The meter doesn't need to use the negative terminal as the reference.

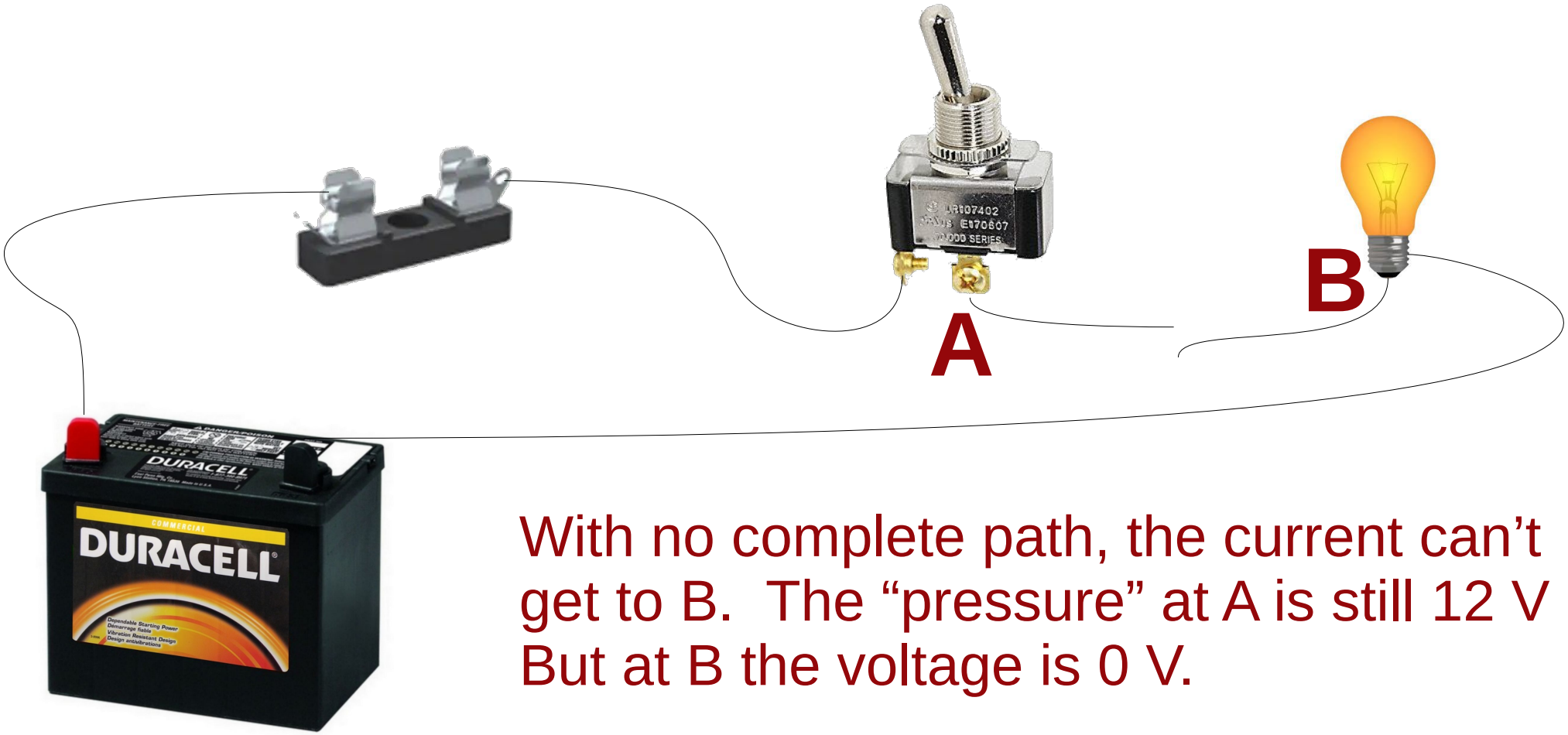
*** = 12 V, relative to battery neg**



What would the meter read here?

Troubleshooting

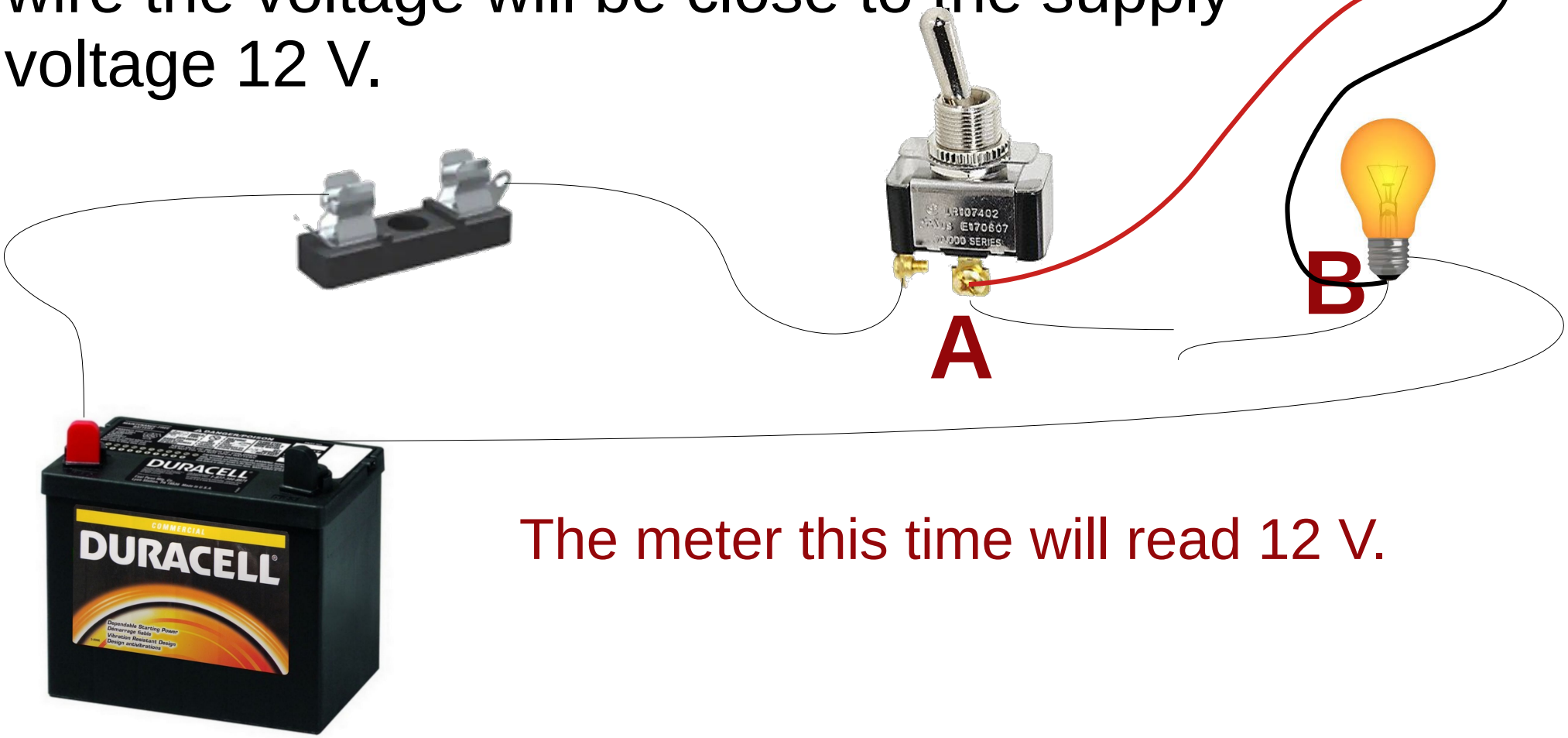
When there is a break in the circuit, how does the voltage at point A compare to B?



With no complete path, the current can't get to B. The "pressure" at A is still 12 V But at B the voltage is 0 V.

Troubleshooting

The voltage (pressure) across an intact wire is close to 0 V. Across a broken wire the voltage will be close to the supply voltage 12 V.



The meter this time will read 12 V.

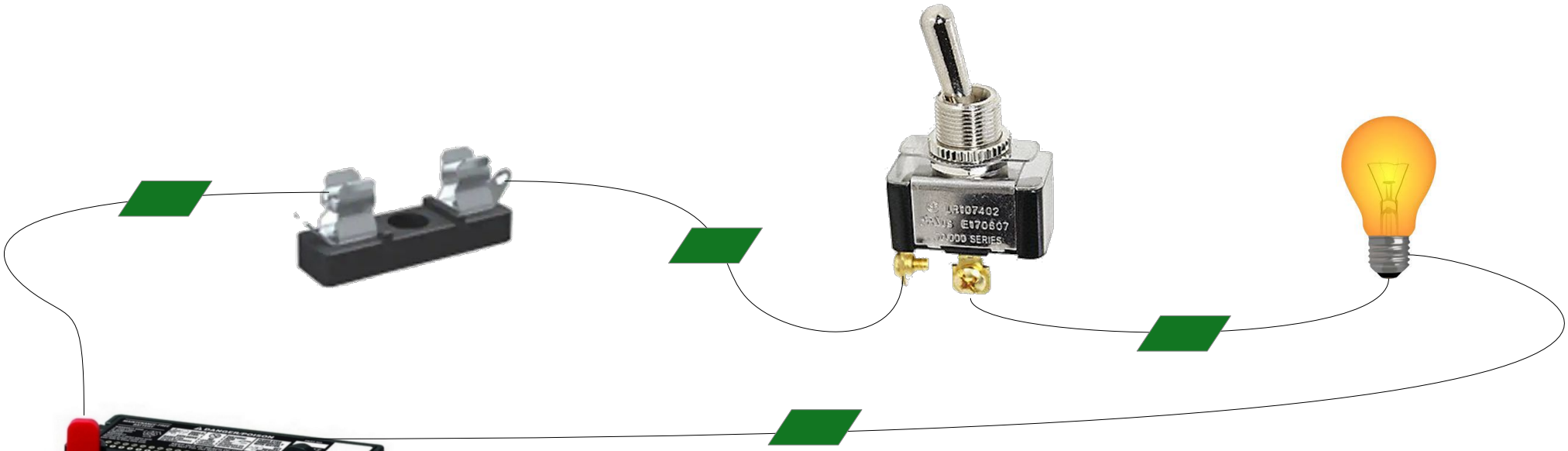
Troubleshooting Summary

$$V = I \times R$$

- Voltage across a low-resistance component (e.g. intact wire) should be low.
- Voltage across a high-resistance component (e.g. open switch, functioning bulb) should be high.

Troubleshooting

Measuring Current, instead of Voltage, is less useful for most troubleshooting.



Why? Because in a series circuit, the current everywhere is the same. An ammeter will read 0 if the circuit is not working, without an indication of WHERE the break is.

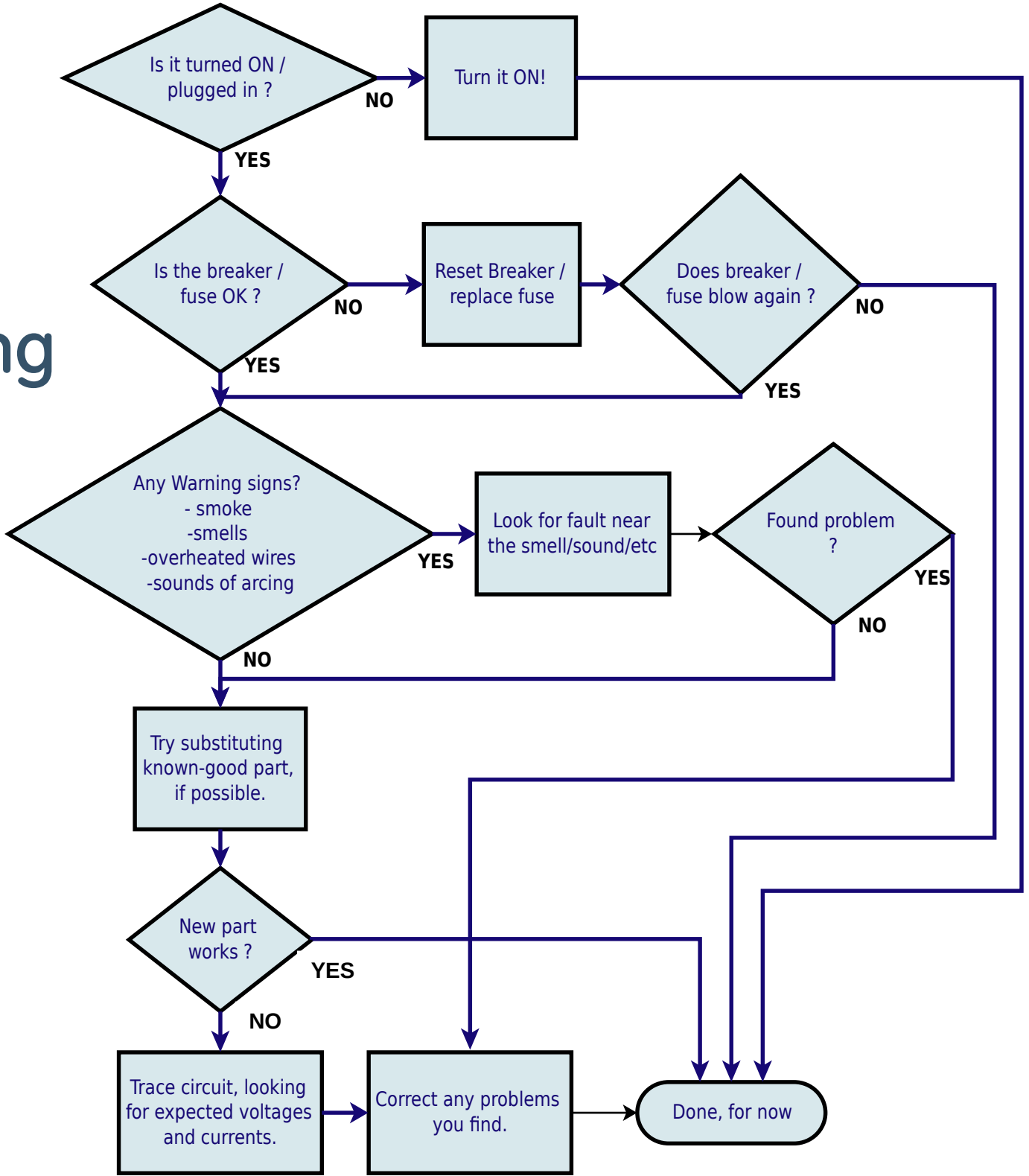
Troubleshooting Exercise

- Choose one or more, based on your experience level:
  - Basic
    - **Measure Voltage and Current in a simple Circuit**
  - Intermediate
    - **Measure Voltage and Current in a multibranch circuit. Calculate Power and other parameters.**
  - Advanced
    - **Diagnose and Fix a non-functioning Circuit.**
  - ***All***: Have your partner 'sabotage' the circuit without you looking, then try locating the fault

Post-Exercise Review

- Questions?
- Observations?

Troubleshooting Flowchart



Troubleshooting

- Useful tool if re-wiring boat and need to follow wires behind bulkheads
- Clip the signaller to the circuit you want to trace (e.g. at the breaker panel)
- Use the handheld tracer to follow the circuit by listening to the tone
- ~$20 online (e.g. dx.com)

Wire Tracer

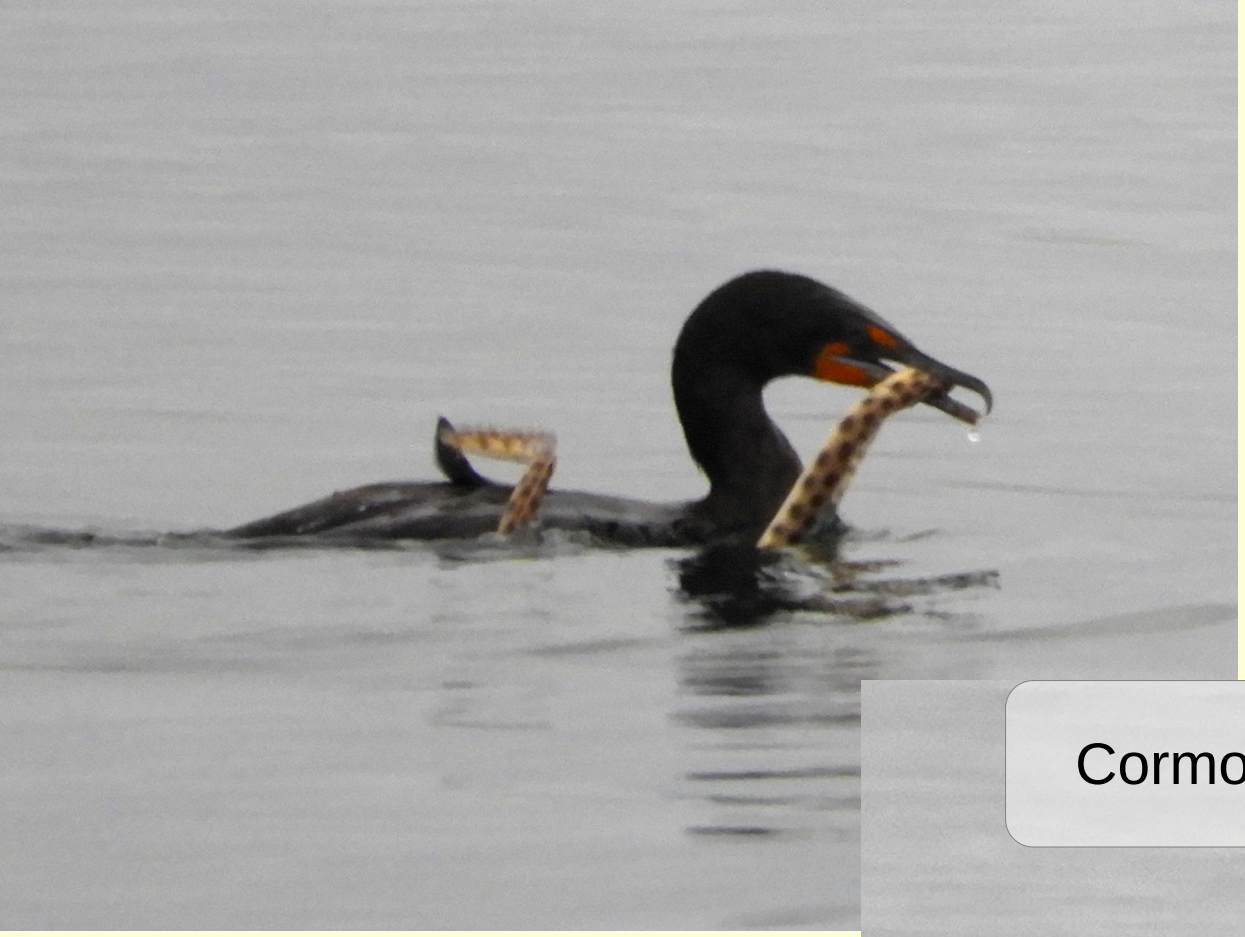
Troubleshooting

Battery State-of-Charge

Measure resting (i.e. no loads) battery voltage

- **Temperature** affects battery voltage. As temperature rises, voltage drops. Correction factor is approx -0.018 V/°C for a 12V battery.

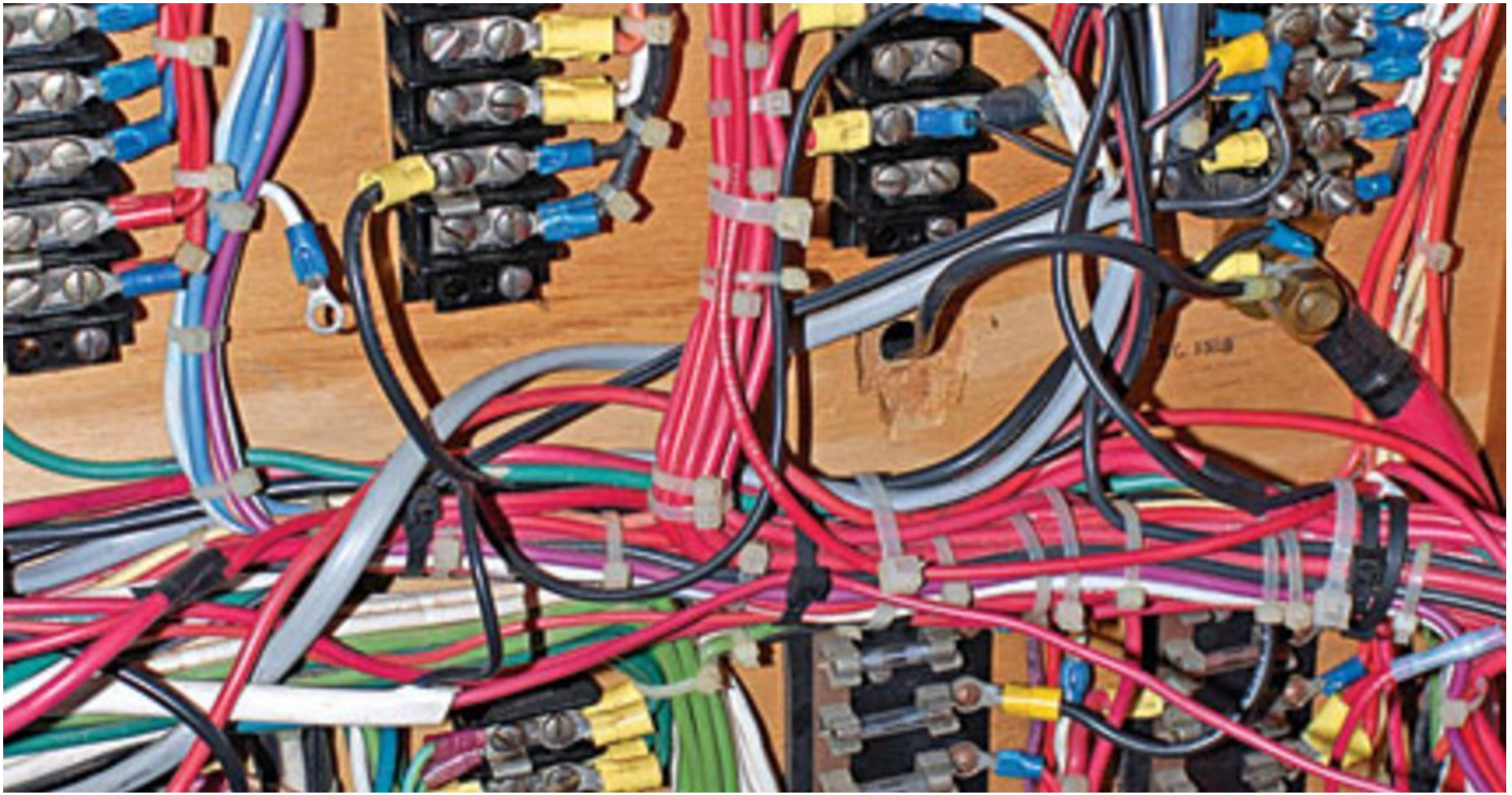
State of Charge	12 Volt battery	Volts per Cell
100%	12.7	2.12
90%	12.5	2.08
80%	12.42	2.07
70%	12.32	2.05
60%	12.20	2.03
50%	12.06	2.01
40%	11.9	1.98
30%	11.75	1.96
20%	11.58	1.93
10%	**11.31**	**1.89**
0	**10.5**	**1.75**



Cormorant with Tiger Snake Eel

Wire Labeling, Circuit Diagrams

How to make sense of it all...



Wire Labeling

ABYC states ”each electrical conductor...shall have a means to identify its function”

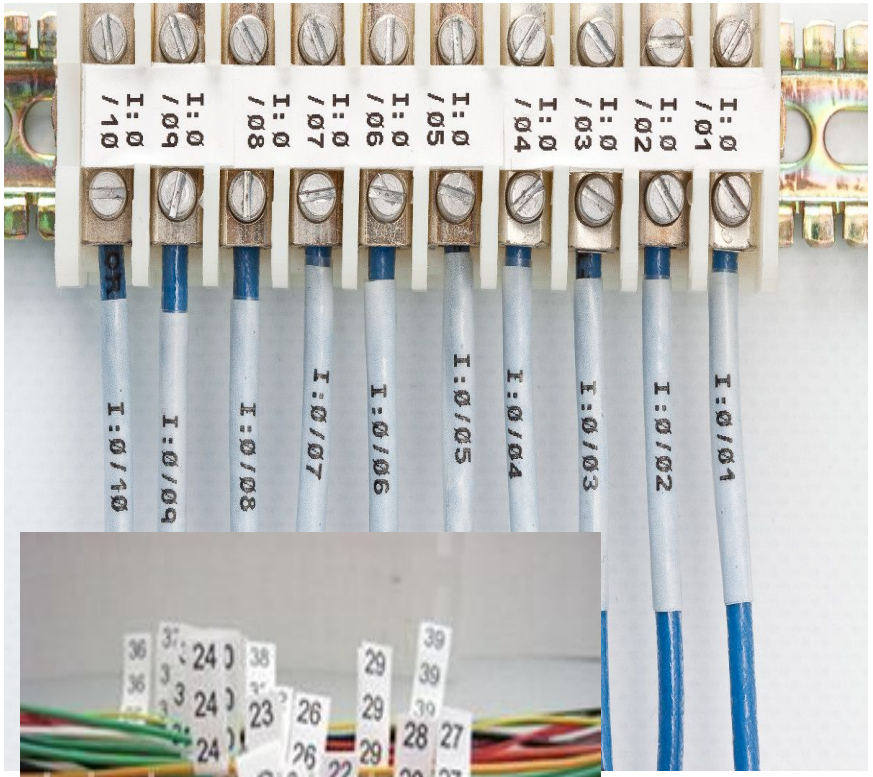
Two common means are **Labels**, and **Colour coding**

Wire Colour Codes

Table 8-5 GENERAL WIRING COLOUR CODE		
Colour	Use	
Green or green w/yellow stripe(s)	DC Grounding Conductors	
Black or Yellow	DC Negative Conductors	
Red	DC Positive Conductors	
Engine and Accessory Wiring Colour Code		
Colour	Item	Use
Yellow w/red strip (YR)	Starting circuit	Starting switch to solenoid
Brown/yellow stripe (BY) or Yellow (Y) – see note	Bilge blowers	Fuse or switch to blowers
Dark Gray (Gy)	Navigation lights	Fuse or switch to lights
	Tachometer	Tachometer sender to gauge
Brown (Br)	Generator armature	Generator armature to regulator
	Alternator charge light	Generator
		Terminal/alternator
		Auxiliary terminal to light to

Source: *Transport Canada Construction Reqt's for Small Vessels*

Wire Labeling

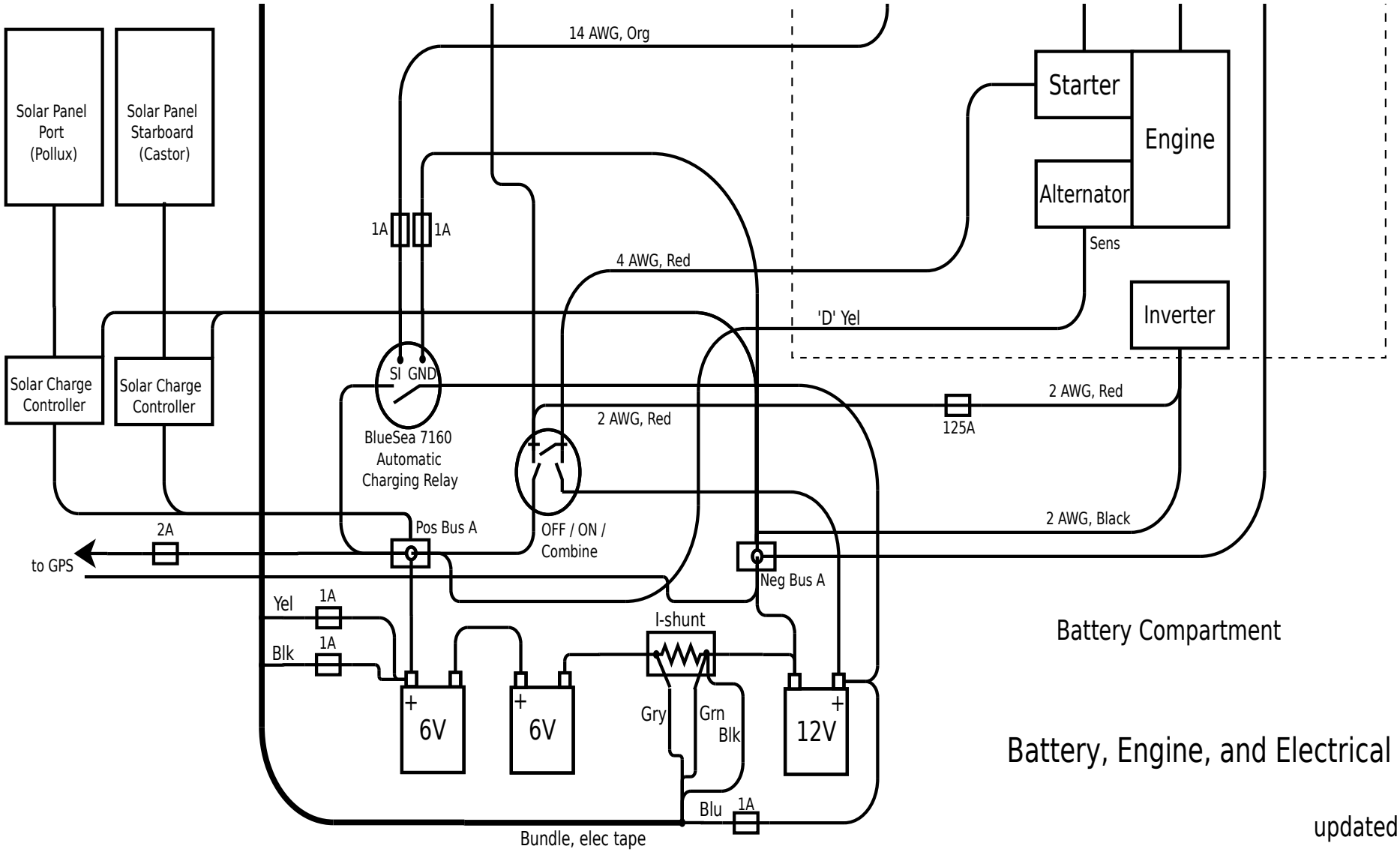


Wire Labeling

Keep a list of your wires and their routing

	A	B	C	D	
1	**Hoku Pa'a Wiring Code**				
2					
3	**Wire #**	**Colour**	**Function**	**Panel Name**	**Routing**
4	4	Red	VHF Radio Power	Subpanel Radio	Electrical Subpanel, E
5	6	Red, Black 14 AWG	GPS & VHF Power at Nav Stn	n/a	Battery compartment,
6	7	Red, Black	AIS Power	AIS	Elec panel, Engine ro
7	8	White 4 cond+shld	Data from Nav Stn to VHF radio	n/a	Nav stn, battery comp
8	9	White	Stereo on/off control	Stereo	Elec panel, eng room
9	10	Black 14AWG	Stereo Gnd	Subpanel	Elec panel, eng room
10	10	White w/ Blk 14AWG	Stereo Power	Subpanel Stereo	Elec panel, eng room
11	11	Blue	Cabin Light Forepeak	Cabin Lights	Stbd aft hanging lock
12	12	Blue	Cabin Light Heads	Cabin Lights	Stbd aft hanging lock
13	13	Blue	Cabin Lights, port side plus some	Cabin Lights	Elec panel, port cabin
14	14	Black multicond.	Pactor Modem Audio, Power	n/a	ACC DIN8 socket on
15	15	Red, Black 10 AWG	Ham/SSB Radio	n/a	Battery compartment,
16	51	Black, Gray multicond	Pactor Modem Radio Control	n/a	REMOTE DE-9 socke
17	60	Red 14 AWG	Fuel Lift Pump	n/a	Engine room port hull

Wiring Diagrams



Battery, Engine, and Electrical Panel Wiring

updated 2015 Jul 8

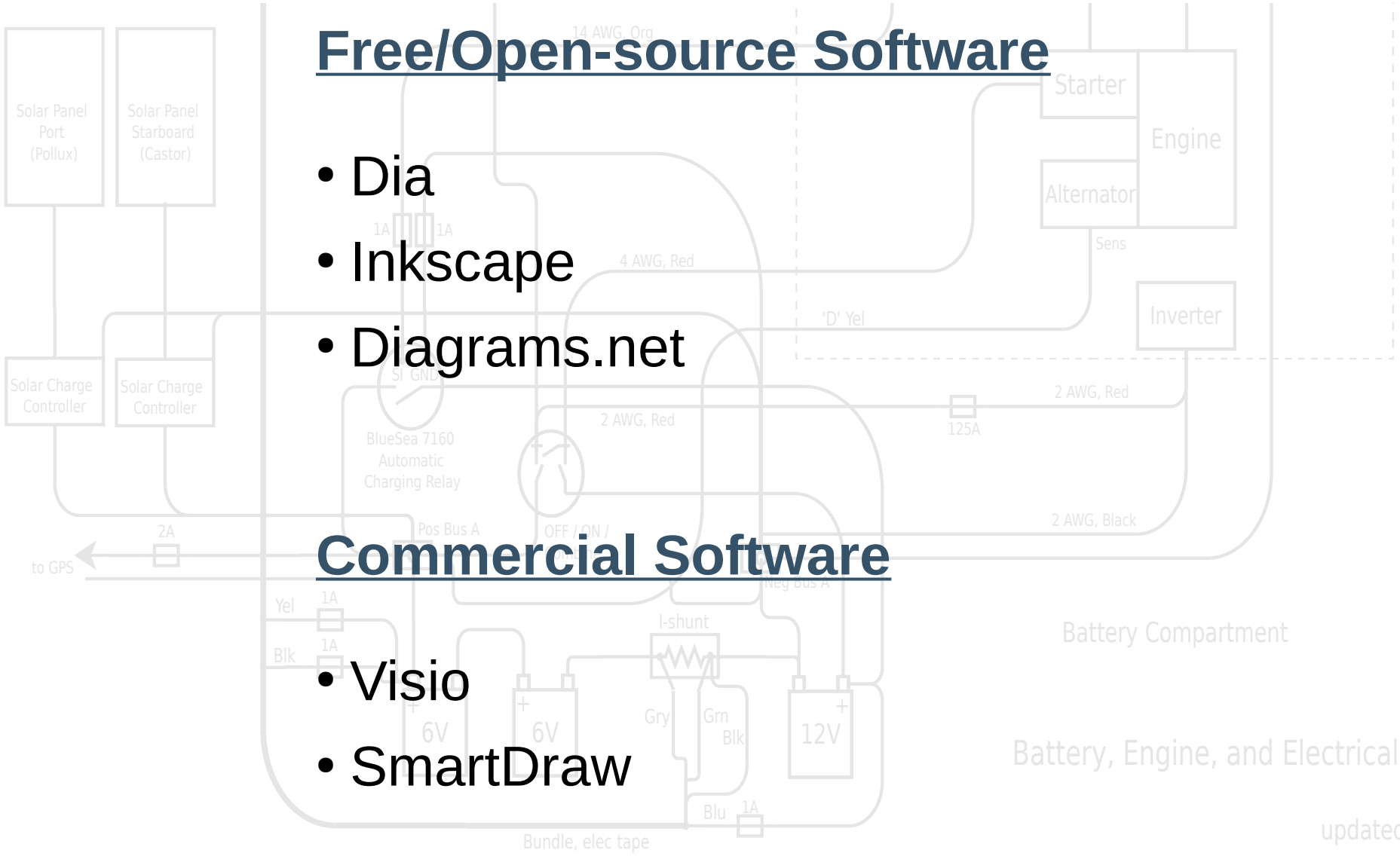
Wiring Diagrams

Free/Open-source Software

- Dia
- Inkscape
- Diagrams.net

Commercial Software

- Visio
- SmartDraw



Resources

- http://www.ancorproducts.com/en/resources/abyc-standards has a good summary of ABYC standards as they apply to wiring
- https://tc.canada.ca/en/marine-transportation/marine-safety/construction-standards-small-vessels-2010-tp-1332-e
  Transport Canada **Construction Standards for Small Vessels *(2010)*** Section 8 deals with Electrical Systems. Majority of content is harmonized with ABYC standard E-11. This is the cheapest (i.e. free) reference source for electrical requirements.
- http://www.blackfinforums.com/sites/default/files/10/attachments/abyc-e-11.pdf ABYC Publication **E-11 AC And DC Electrical Systems on Boats *(2008)*** *note that ABYC has issued a 2012 edition but it is not readily available without a membership/subscription to ABYC.
- https://webstore.iec.ch/publication/709 IEC 60092-507:2014 Electrical Installations in Ships – Part 507: Small Vessels. Gives requirements for the design, construction and installation of electrical systems in small vessels. Requires purchase to download.
- https://www.boatus.com/expert-advice/expert-advice-archive/2021/february/analyzing-onboard-fire-claims
  Boat US report on top six causes of boat fires. Also has informative pictures and recommendations.
- https://forum.digikey.com/t/crimping-ring-terminals/4896 Describes steps for crimping terminals. Digikey is also a good supplier of crimp terminals.
- https://www.molex.com/pdm_docs/ats/TM-640160065.pdf Very detailed document on crimping with both hand tools and automated equipment.

Resources

- radioworld.ca Toronto-based radio and accessories supplier. Quick mail-order for coax, connectors, etc.

- Whitesquallconsulting.com Ladysmith-based Martin Dunsmuir. Good prices on Pactor modems

- Roton.ca Vancouver-based boating outfitter. Usually good bulk-purchase deal on ICOM M-802 around January boat-show time

- www.universal-radio.com/catalog/cable/coaxperf.html Table of coax losses and power-handling

- www.hcarc.us/articles/soldering%20PL-259%20connectors.htm Procedure for assembling PL-259 connectors

- en.wikipedia.org/wiki/Monopole_antenna Article on Monopole Antennas (the most common configuration of sailboat HF antenna)

- www.kp44.org/ftp/SeawaterGroundingFor_HF_Radios_byGordonWest.pdf Test results of 4 types of Ground Plane on 40 foot yacht

- https://batteryuniversity.com/learn/article/charging_the_lead_acid_battery lots of useful info about batteries

- https://volts.ca/ Canadian distributor for lithium batteries, solar panels, etc

- https://wegosolar.com Local (Chemainus, BC) distributor for lithium batteries and related solar products

Resources

Books

- *Marine Electrical and Electronics Bible,* John C. Payne, 1998
- *Boatowner's Illustrated Handbook of Wiring,* Charlie Wing, 1993
- *Boatowner's Illustrated Electrical Handbook,* Charlie Wing, 2006
- *The Boatowner's Guide to Corrosion,* Everett Collier, 2006

That's It !

- Questions ?