How To:
Marine Electrical Seminar

Improving electrical systems on your boat.

Created by Jeff Cote of Pacific Yacht Systems, Inc.
www.pysystems.ca

Electrical & Electronics Fundamentals & Troubleshooting Tips

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Before we get started . . .

- Cell phones off please
- Ask questions
- Take lots of notes / drawings
- All slides will be provided to you online

Electrical Fundamentals

Voltage
Amps
Resistance
DC
AC

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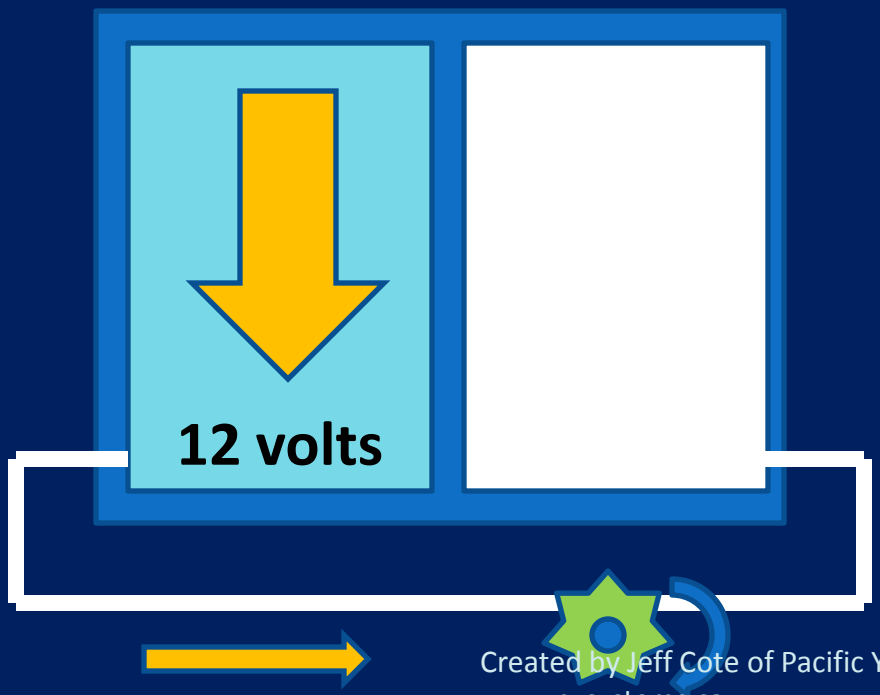
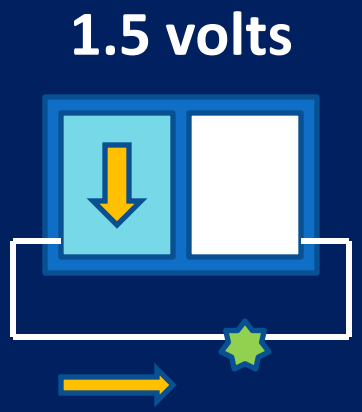
What is Voltage?

- Amount of potential energy between two points
- Greater the voltage, greater the potential current flow





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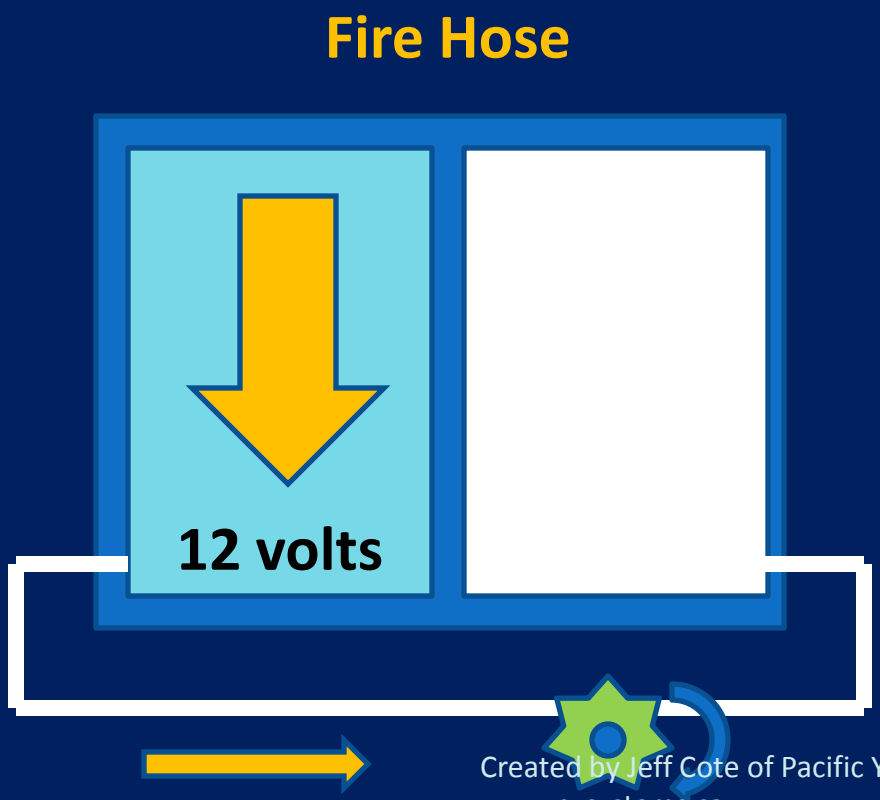
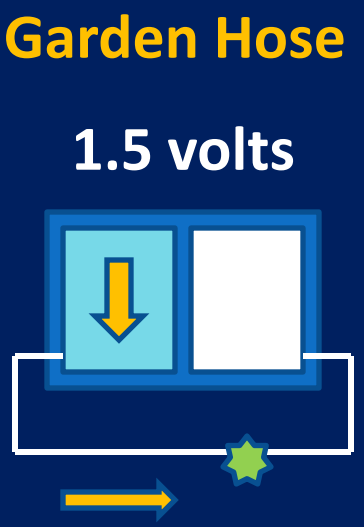
What is Voltage?

- Let's compare voltage to water pressure





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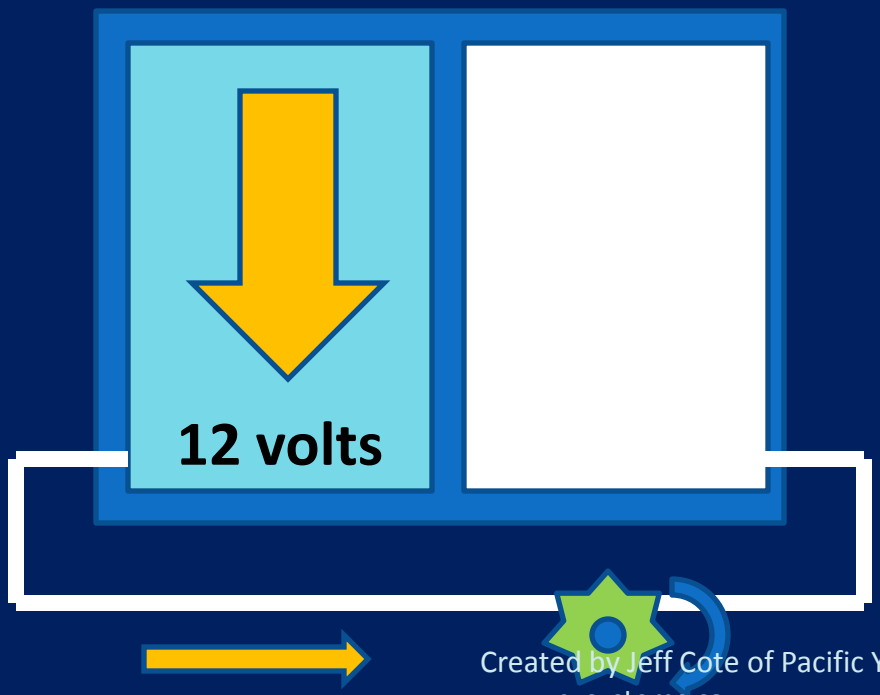
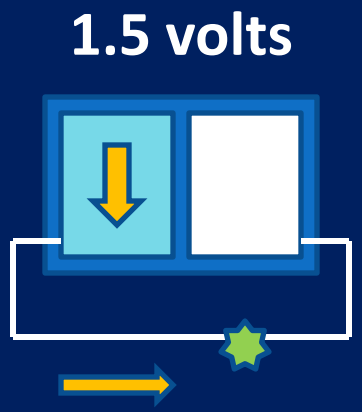
What is Voltage?

Voltage is like water pressure. The greater the pressure (voltage), the greater the potential energy.





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What is resistance?

- Let's continue our water analogy
- Water (electrical current) is flowing through the hose

- What might create resistance - restrict the flow?

What is resistance?

- Stepping on the hose will create resistance

- The restriction slows the flow of current

What is resistance?

- Inserting a very small hose will create more resistance

- This will slow the flow of current even more

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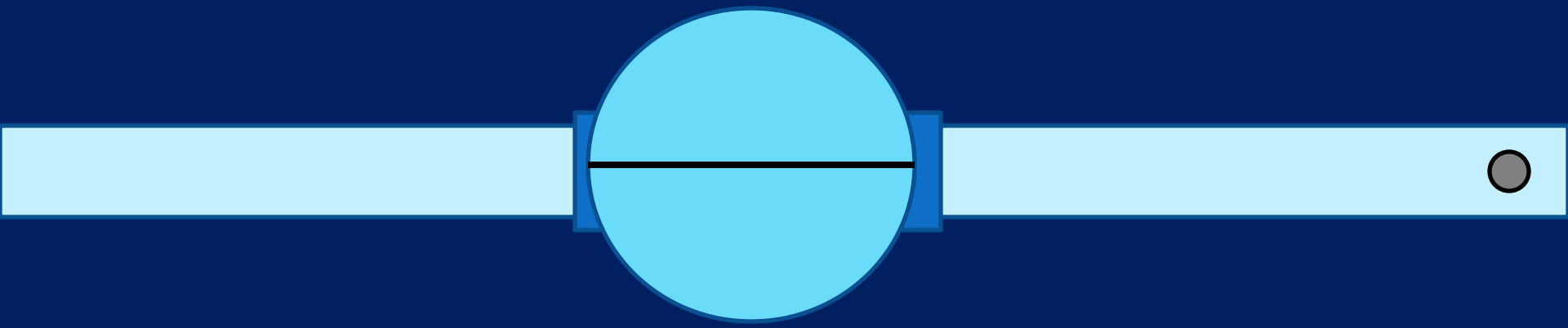
What is resistance?

- A light bulb contains a small wire called a filament



- It creates resistance and slows the flow of current

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What is resistance?

- A light bulb contains a small wire called a filament

- It creates resistance and slows the flow of current

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Ohm's Law

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

Units of Measure

Current: **amps**

Voltage: **volts**

Resistance: **ohms**

$$\text{amps} = \frac{\text{volts}}{\text{ohms}}$$

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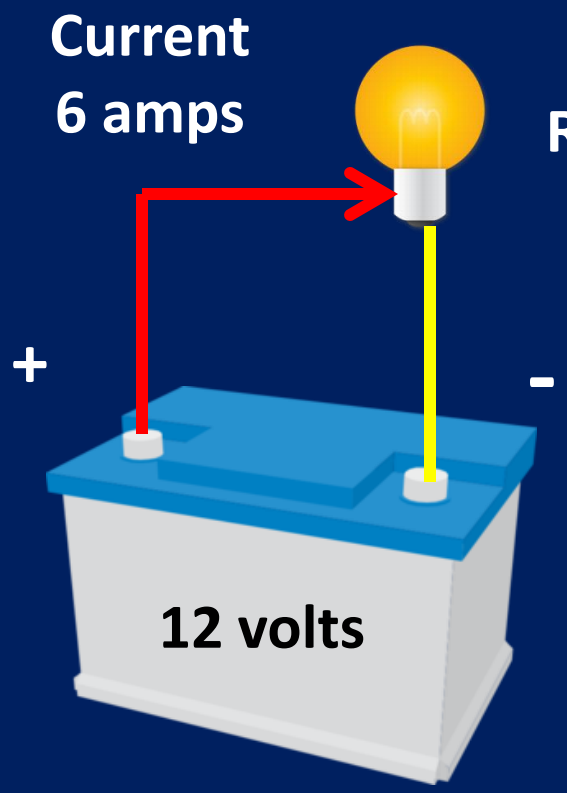
Ohm's Law



$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$\text{??? amps} = \frac{\text{12 volts}}{\text{2 ohms}}$$

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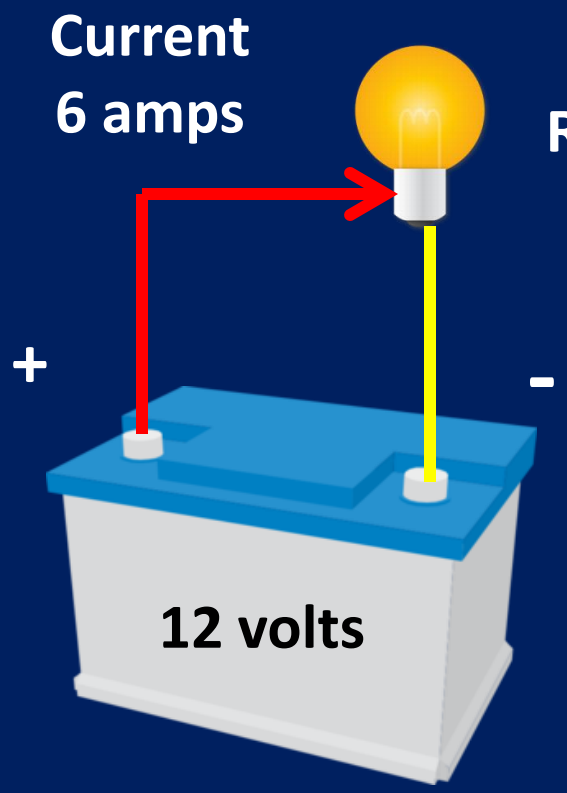
Ohm's Law



$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$6 \text{ amps} = \frac{12 \text{ volts}}{2 \text{ ohms}}$$

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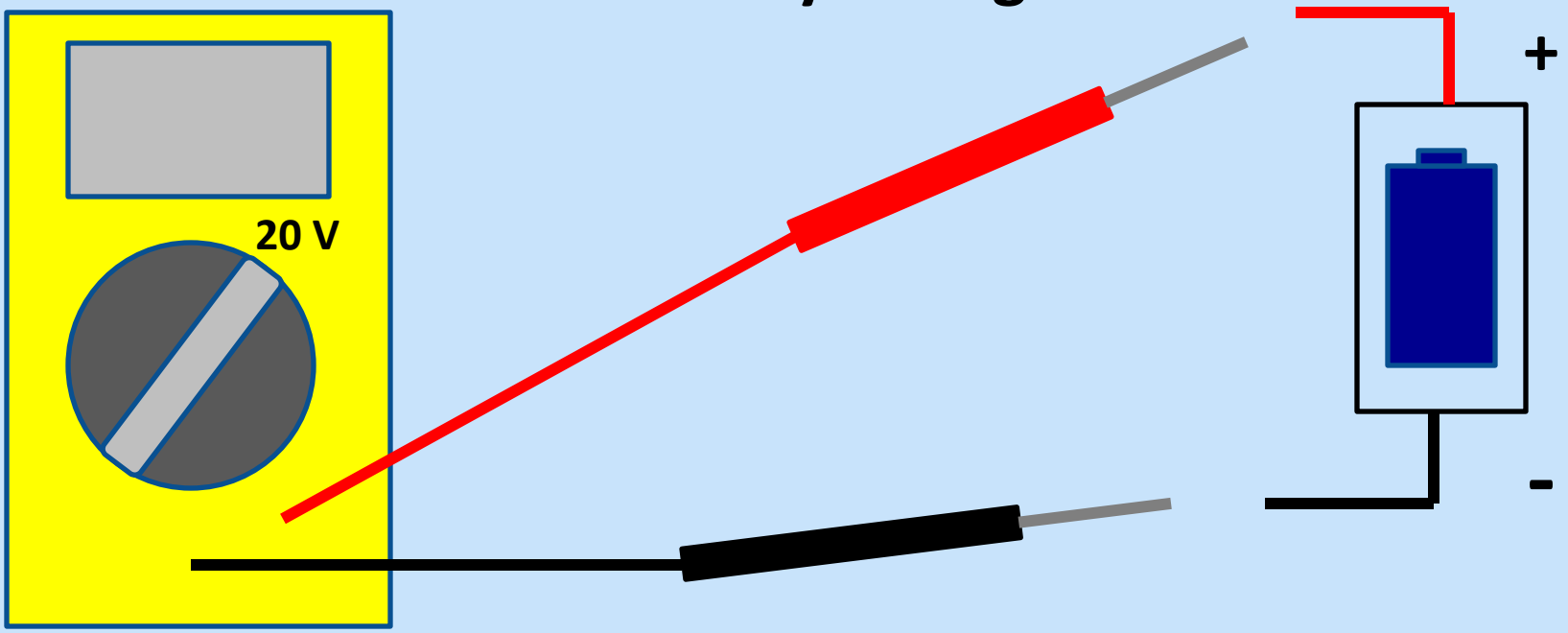
Example 1

Batteries in series & parallel

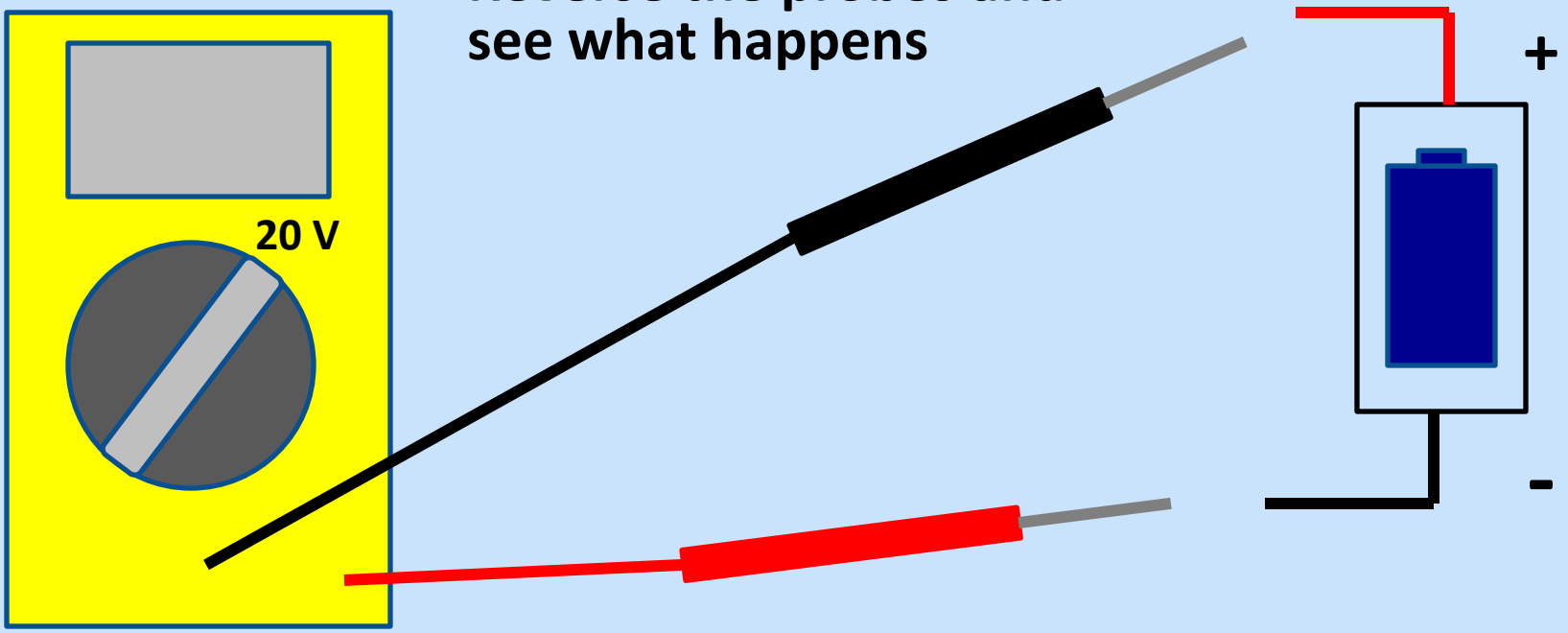
Find battery voltage



Example 2

Batteries in series & parallel

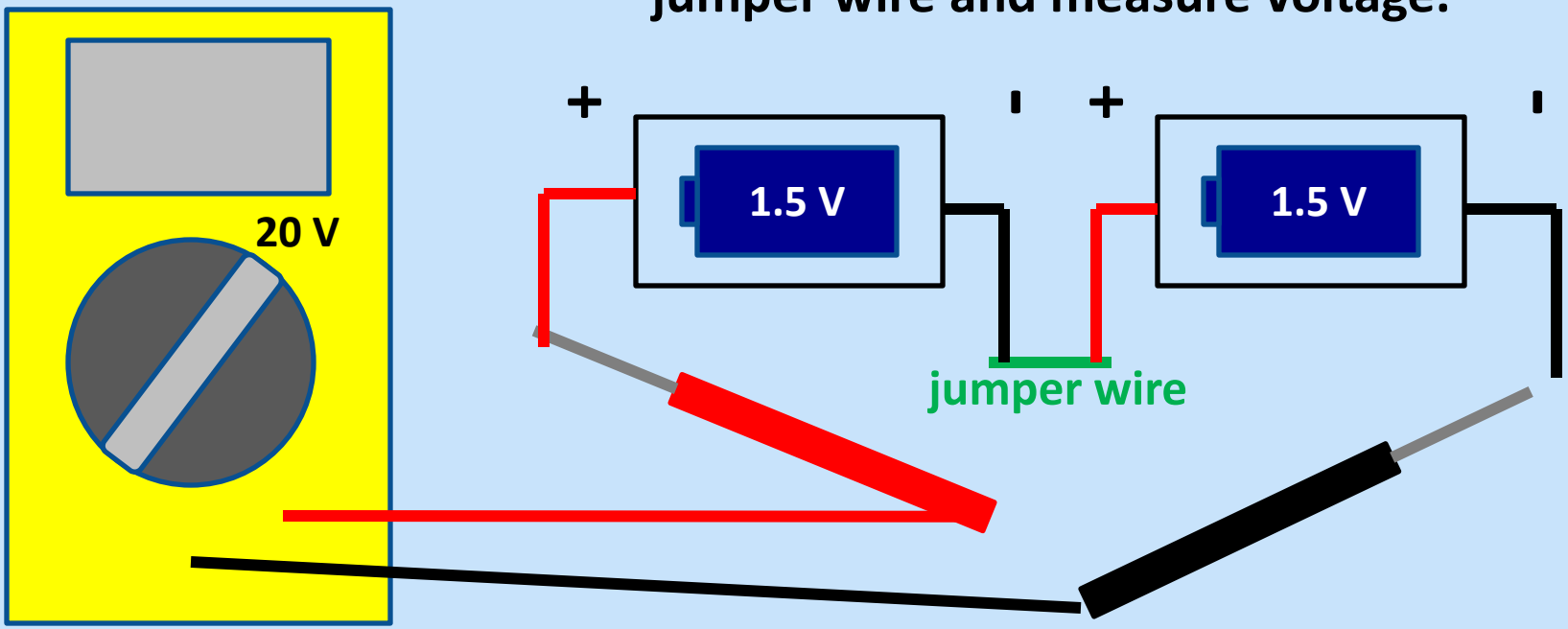
Reverse the probes and see what happens



Example 3

Batteries in series

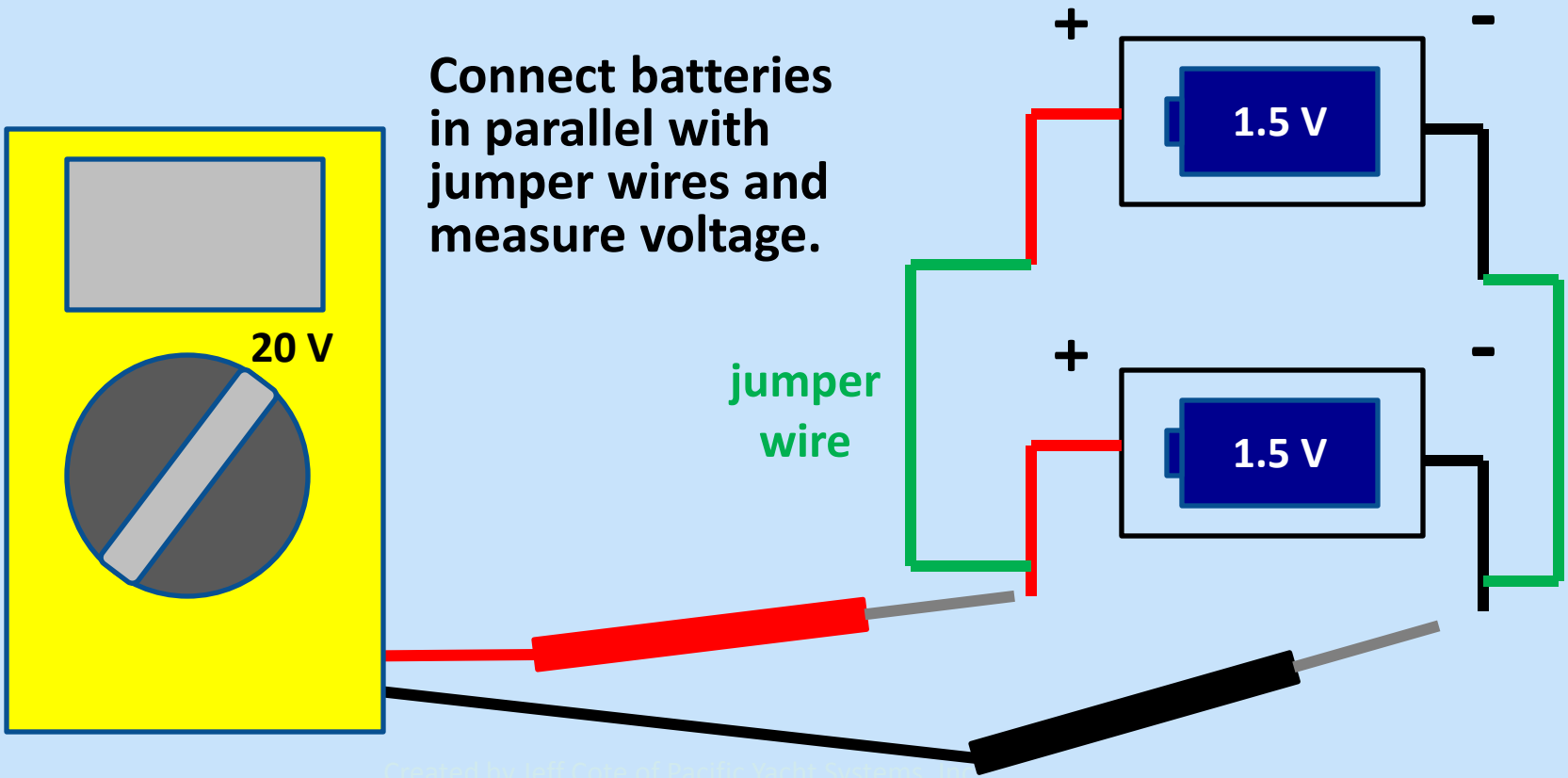
Connect batteries in series with jumper wire and measure voltage.



Example 4

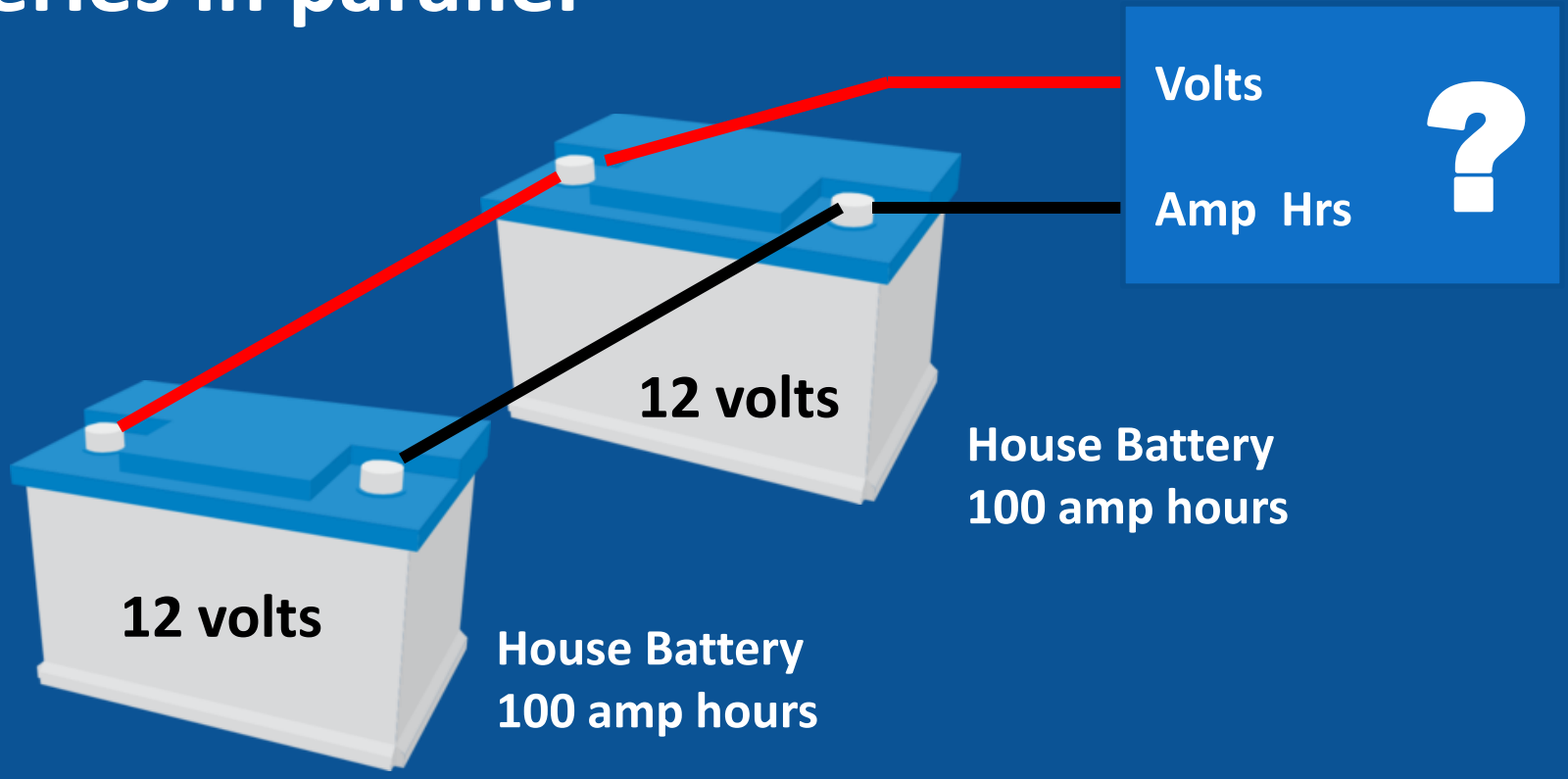
Batteries in parallel

Connect batteries in parallel with jumper wires and measure voltage.



HANDS ON TRAINING

Batteries in parallel



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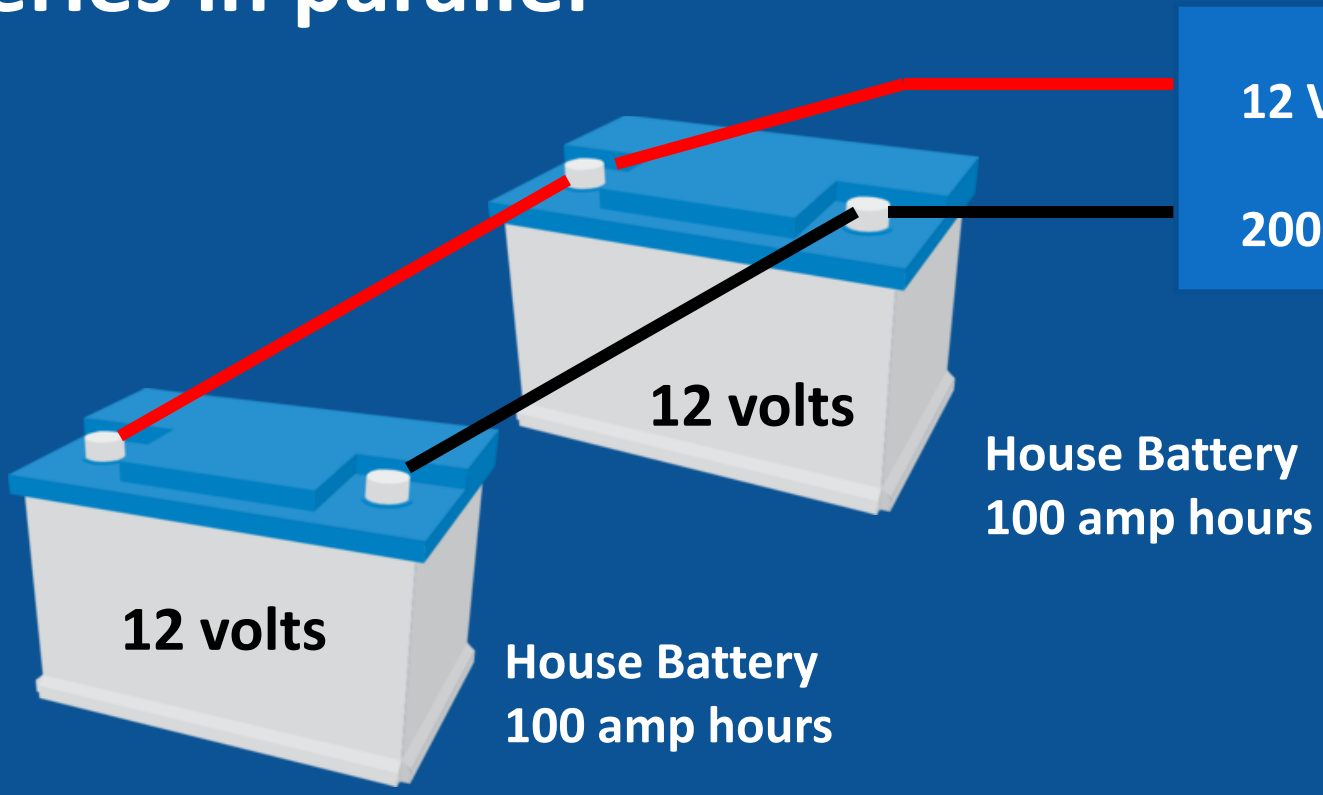
HANDS ON TRAINING

Batteries in parallel



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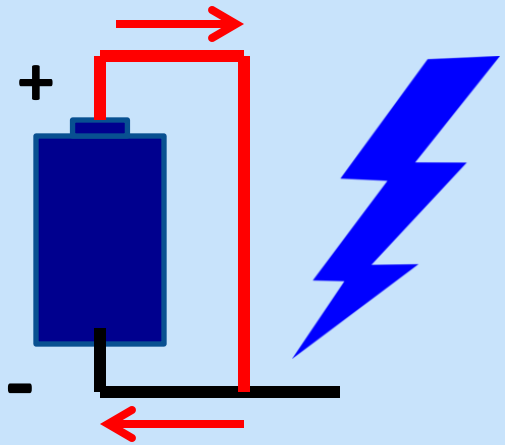
Electrical short circuits

- Happens when wire chafes through or disconnects
- Positive wire makes contact directly with ground
- Result is a huge current flow



Short Circuit

Wire can melt

Biggest cause of boat fires

Properly located and sized fuse or breaker should protect

POWER: Introducing the **watt**

- **Power:** actual rate of doing work
- Good comparison might be calories being burned
- Unit of measure of electrical power is the **watt**
- Examples of electrical work being done on a boat:
  - Light bulb glowing: **6o watts**
  - VHF radio transmitting: **25 watts**
  - Windlass motor turning: **1200 watts**

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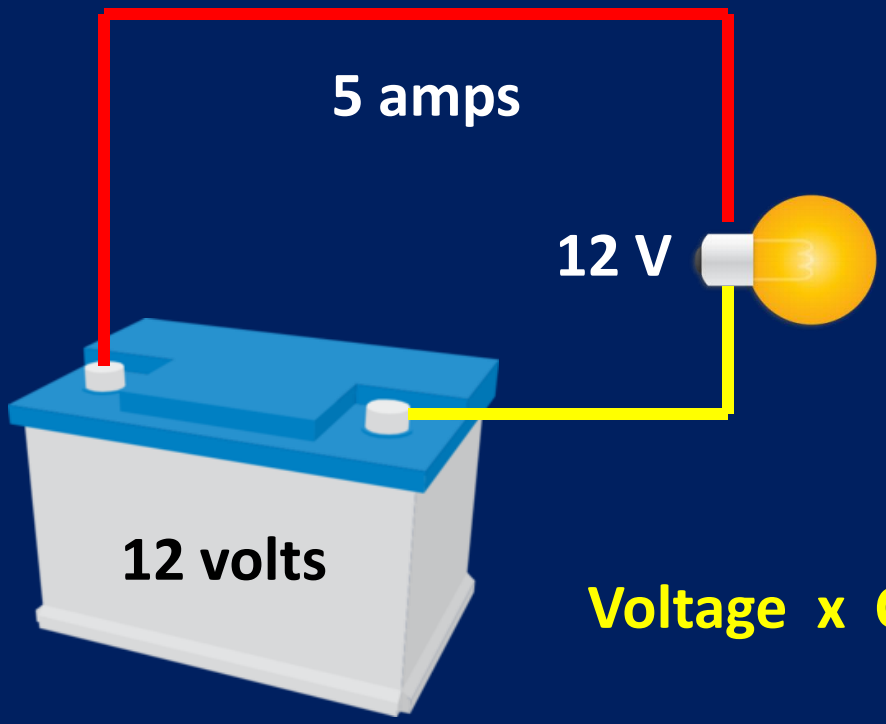
POWER: Introducing the **watt**



60 watt light bulb

Voltage x Current = Power

12 volts x 5 amps = 60 watts

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Converting watts to amps

- Amps are a measurement of current (electron flow)
- Amps vary widely based on voltage in circuit
- Amps influence
  - size of wire to use for heat / fire
  - size of wire for long wire run (voltage drop)
  - size of fuse or breaker

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Converting watts to amps
Example: Microwave on 120 VAC

1200 watt Microwave

Voltage x Current = Power

$$\text{Current} = \frac{\text{Power (W)}}{\text{Voltage (V)}}$$

$$\text{Current} = \frac{1200\ \text{W}}{120\ \text{V}} = 10\ \text{A}$$

- **Typical residential breaker is 15 amp.**
- **Typical wire size is 14 gauge.**

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Converting watts to amps Example: Windlass at 12 VDC

1200 watt windlass

$$\text{Current} = \frac{\text{Power (W)}}{\text{Voltage (V)}}$$

$$\text{Current} = \frac{1200\ \text{W}}{12\ \text{V}} = 100\ \text{A}$$

- **125 amp breaker (1.25 X Current Rating)**
- **Minimum wire size 0**

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Converting watts to amps Example: Windlass at 13.5 VDC

1200 watt windlass

$$\text{Current} = \frac{\text{Power (W)}}{\text{Voltage (V)}}$$

$$\text{Current} = \frac{1200\ \text{W}}{13.5\ \text{V}} = 89\ \text{A}$$

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Converting watts to amps Example: Windlass at 24 VDC

1200 watt windlass

$$\text{Current} = \frac{\text{Power (W)}}{\text{Voltage (V)}}$$

$$\text{Current} = \frac{1200\ \text{W}}{24\ \text{V}} = 50\ \text{A}$$

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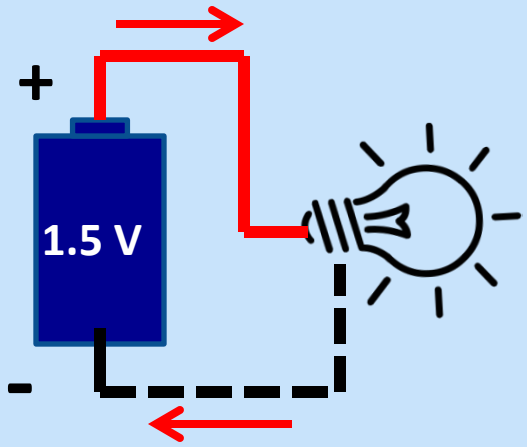
DC - Direct Current

- Current (electrons) flow in one direction
- Normally associated with batteries & solar panels
- Can also be generated electronically



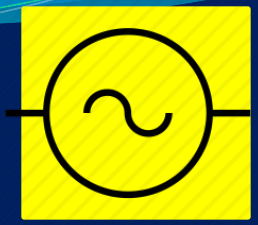
DC Circuit

1.5 Volts - Direct Current

Expressed as: 1.5 V DC

Boats: 12 V DC or 24 V DC

AC - Alternating Current



- **Standard type of power used in our homes**
- **Also shore power or generator**
- **Typical household voltage is 120 volts**
- **Current (electrons) flow in both directions**

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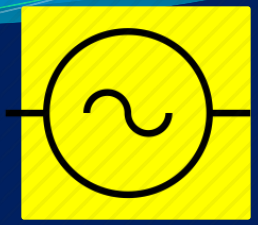
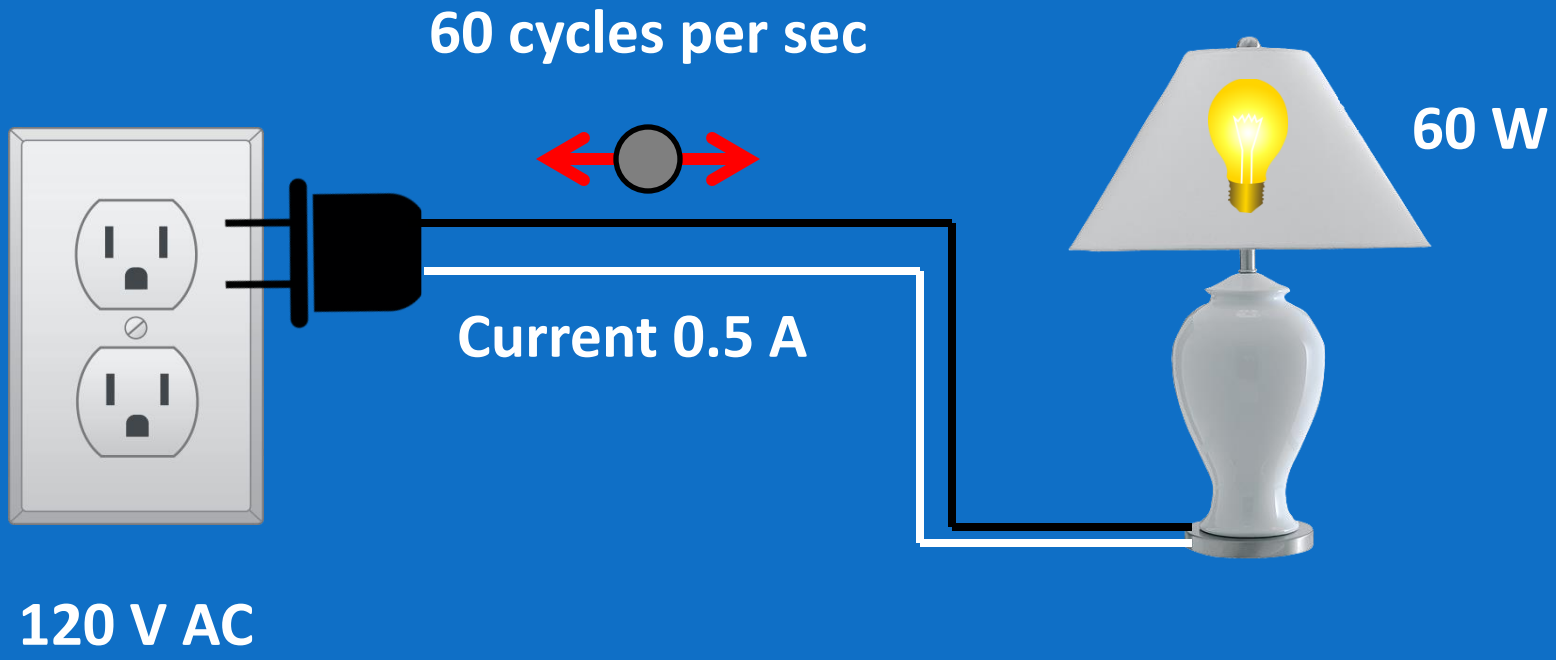
AC - Alternating Current





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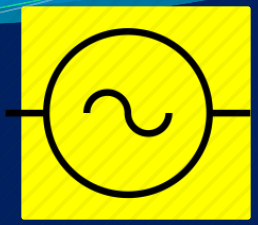
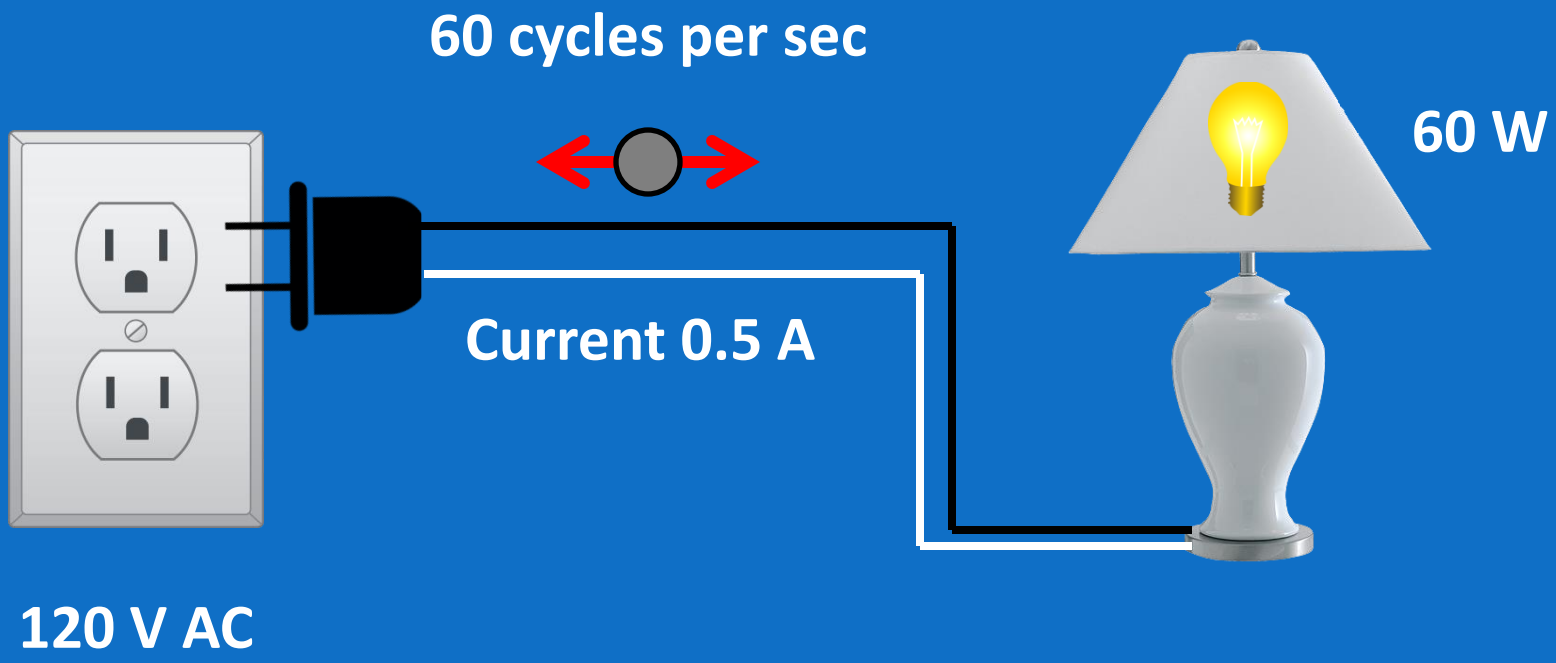
AC - Alternating Current





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Electrical Fundamentals: Wiring Essentials

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Marine Wiring Standards

- Safety standards apply to marine electrical wiring
  - Protect you from fire and electrocution
  - Reliable operation of devices
- Follow ABYC standards
  - **ABYC Standard E-11**

- **Do It Right the First Time**

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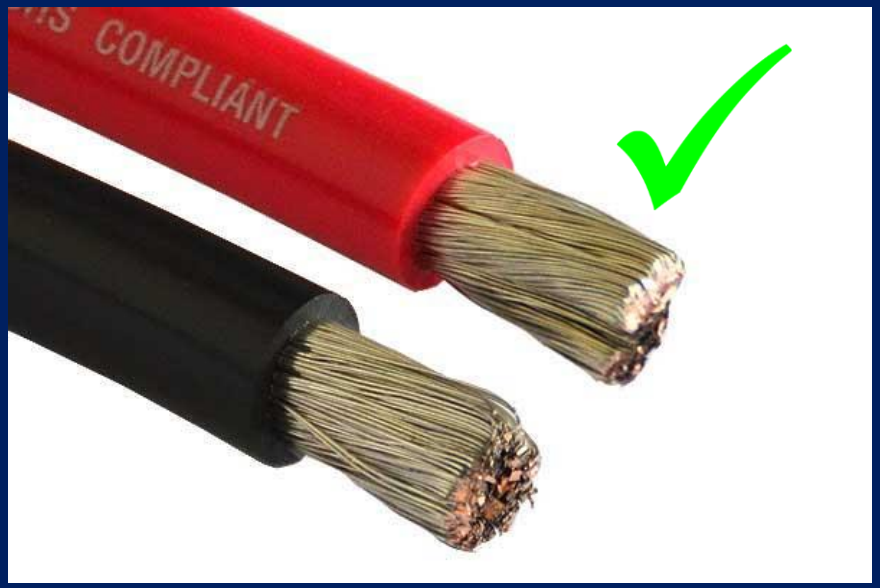
On boats use only braided wire

Solid copper household wire. Do NOT use this!



Proper marine grade braided copper wire that has been tinned.

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ABYC Marine Color Code

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12 VDC Marine Wire Colours

Marine Wire Color Codes – DC Systems Less Than 50 Volts

Color	Item	Use
Yellow or Black[1]	Ground	Return, Negative Mains
Lt. Blue	Oil Pressure	Oil Pressure Sender to Gauge
Dk. Blue	Cabin & Instrument	Fuse or Switch to Lights
Brown	Generator Armature	Generator Armature to Regulator
	Alternator Charge Light	Generator Terminal or Alternator Auxiliary Terminal to Regulator
	Pumps	Fuse or Switch to Pumps
Green	Bonding System	Bonding Wires (if insulated)
Grey	Navigation Lights	Fuse or Switch to Lights
	Tachometer	Tachometer Sender to Gauge
Orange	Accessory Feed	Ammeter to Alternator or Generator Output and Accessory Fuses or Switches
	Common Feed	Distribution Panel to Accessory Switch
Pink	Fuel Gauge	Fuel Gauge Sender to Gauge
Purple	Ignition	Ignition Switch to Coil & Electrical Instrument
	Instrument Feed	Distribution Panel Electrical Instruments
Red	Main Power Feeds	Positive Mains (particularly un-fused)
Yellow	Generator Field	Generator to Regulator Field Terminal
Brown w/Yellow	Bilge Blowers	Fuse or Switch to Blower
Yellow w/Red	Starting Circuit	Starting Switch to Solenoid

1. Since marine AC systems use black wires as the current carrying wire (hot), black is being phased out on marine DC systems to help prevent confusion.

12 VDC Polarity

- **Most DC devices are polarity sensitive.**
  - **Won’t work if polarity is reversed**
  - **Devices might be damaged**
- **This bilge pump would run backwards if polarity was reversed!**

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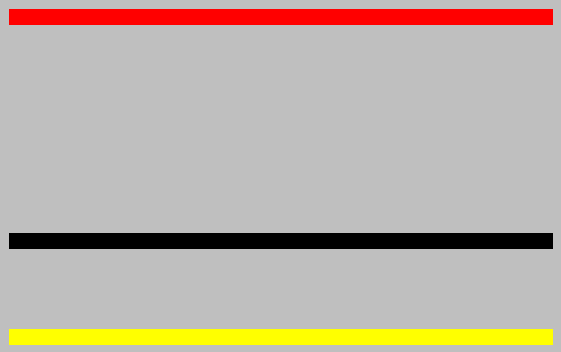
12 VDC marine wire colours



Red: Positive / Power Supply

Black or Yellow: Negative / Ground

Know this. And don't ever touch Pos & Neg wires together!

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120 VAC wire colours

Black: Hot (most dangerous)

White: Neutral

Green: Ground

Use extreme caution. Shut off AC power and test first!

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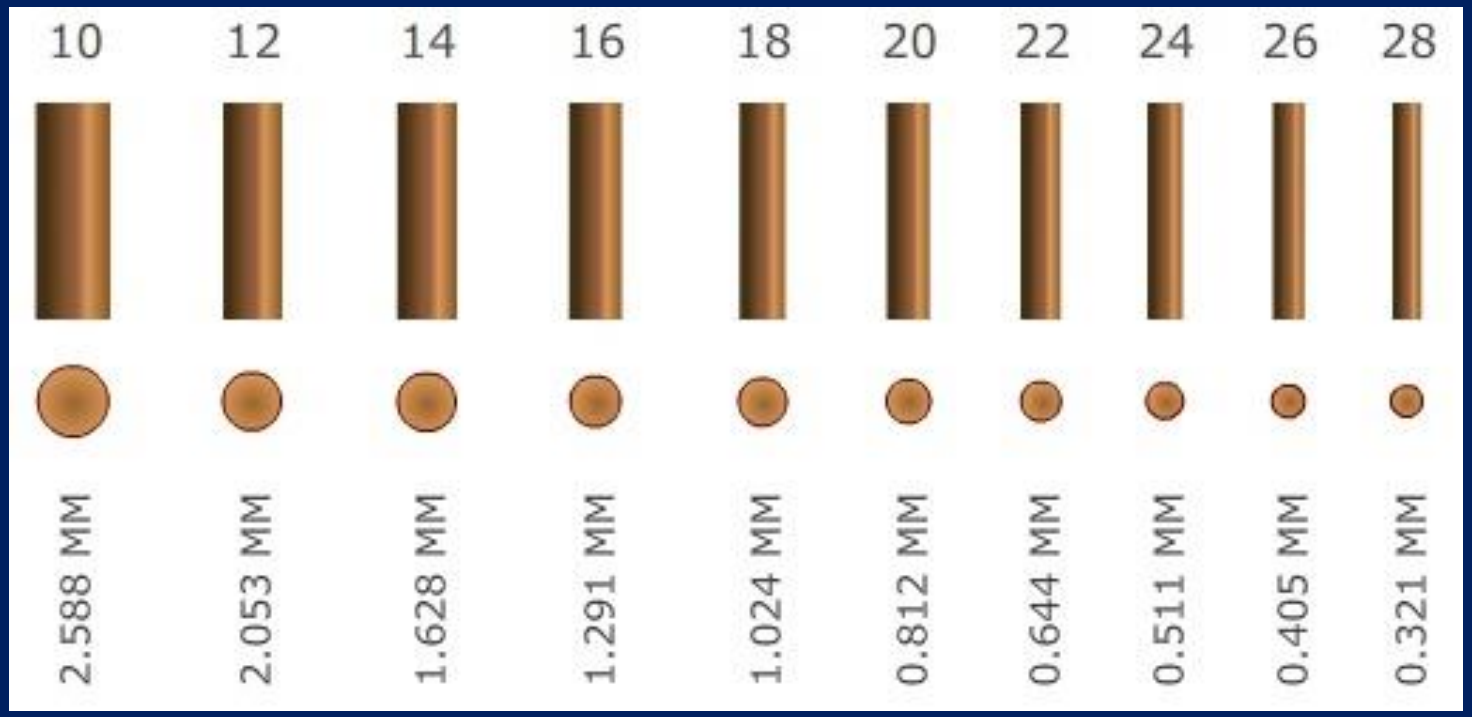
Wire Gauge (wire diameter)



The smaller the number - the thicker the wire.

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Wire Gauge & Risk of Fire

- Thicker wire will carry more current (amps)
- If wire is too small for the current it gets hot
- If way too small **it will catch fire**

Use a **Wire Ampacity Table** to determine correct wire size for current in your circuit.

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Wire Gauge & Voltage drop

- All wire has some resistance
- Can be a problem in 12 / 24 VDC circuits
- Longer the wire -> more the resistance
  - Result is **voltage drop** -> device will might NOT work
- Thicker wire has more copper - less friction
- Easily calculated with **Wire Voltage and Amperage Table**

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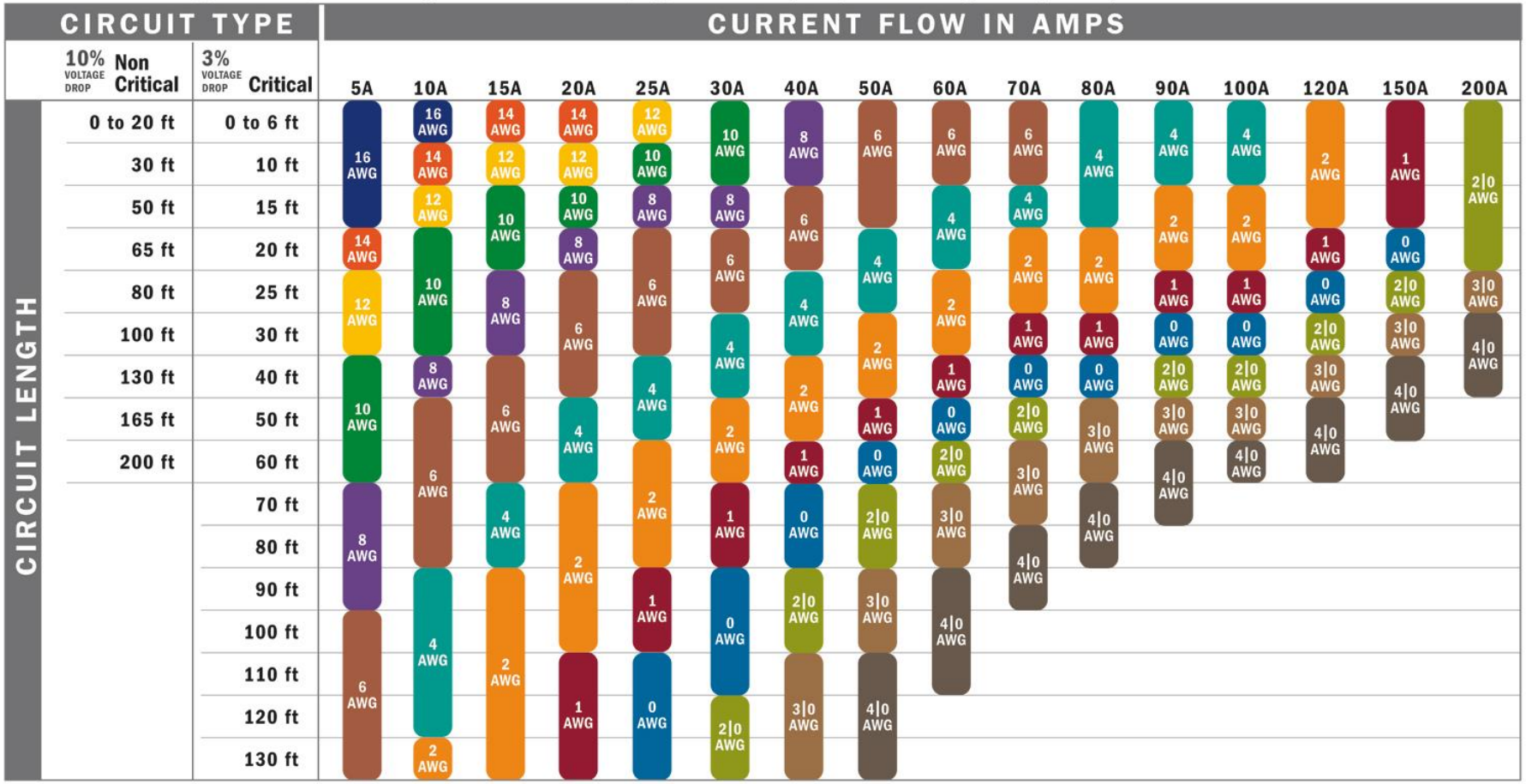
Wire Ampacity & Voltage Table

U.S. Coast Guard regulation requires all ungrounded current carrying conductors (except the starting circuit) to be protected with a circuit breaker or a fuse.

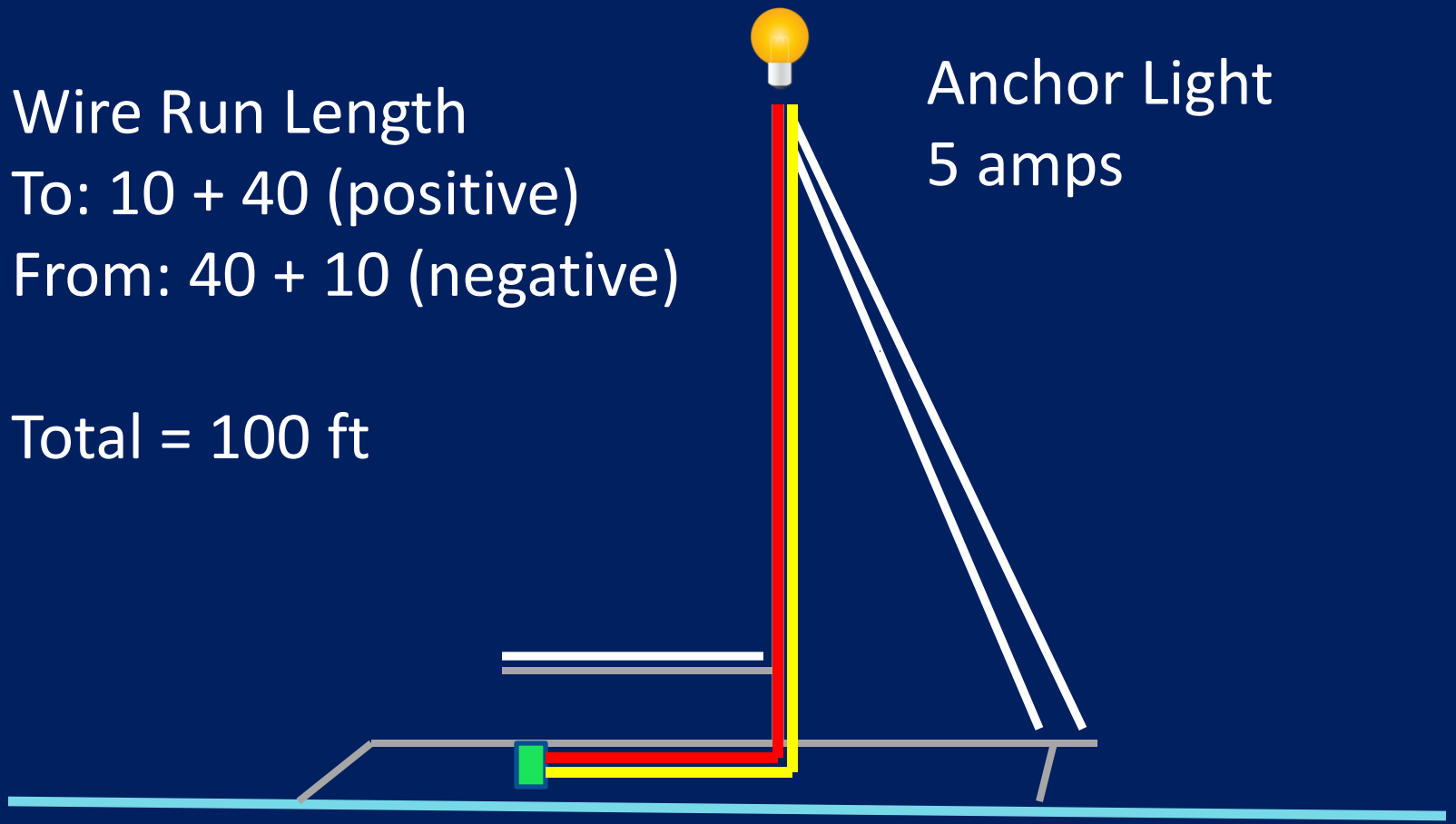


Although this process uses information from ABYC E-11 to recommend wire size and circuit protection, it may not cover all of the unique characteristics that may exist on a boat. If you have specific questions about your installation please consult an ABYC certified installer.

Voltage Drop & Wire Length Example: Anchor Light

Wire Run Length
To: 10 + 40 (positive)
From: 40 + 10 (negative)

Total = 100 ft



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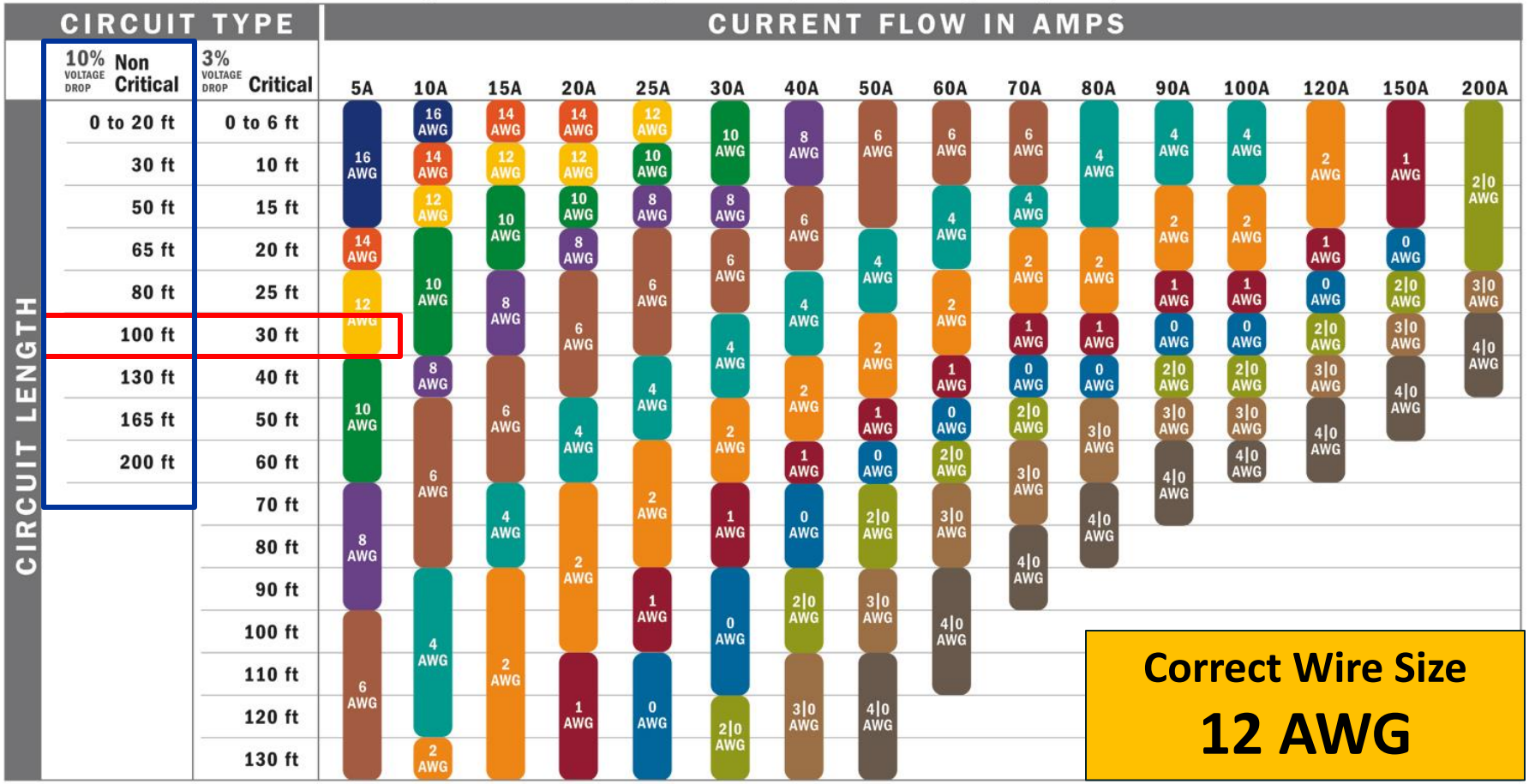
Wire Ampacity Table

U.S. Coast Guard regulation requires all ungrounded current carrying conductors (except the starting circuit) to be protected with a circuit breaker or a fuse.



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Fuses - to protect wires

- Wires can catch fire with too much current
  - Short circuit
  - Too small wire for load
- The fuse becomes the WEAK LINK in the wire
  - designed to blow first
  - protects the wire
- Locate the fuse close to the power source

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Fuses - to protect wires

Fuses come in many styles and amp ratings

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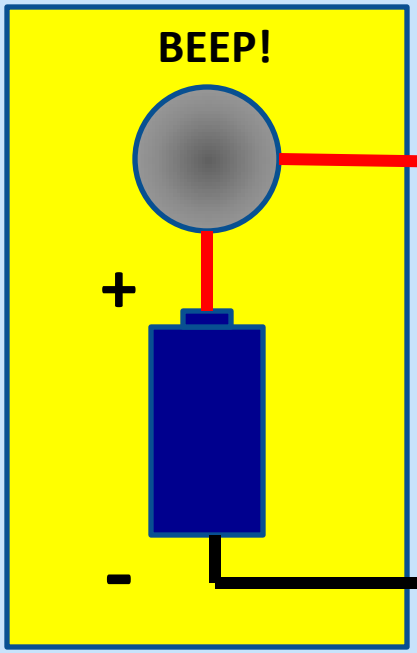
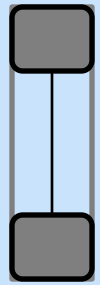
Continuity (Ohms) Test

Testing a fuse is easy!



Set meter to continuity symbol



Continuity (Ohms) Test

Testing a fuse is easy!

Set meter to continuity symbol

Fuses and Circuit Breakers

- Safety reminder
  - Prevents fire
  - Prevents electrocution
  - Safeguards critical equipment
- Electrical kill switch
- Breaks connection

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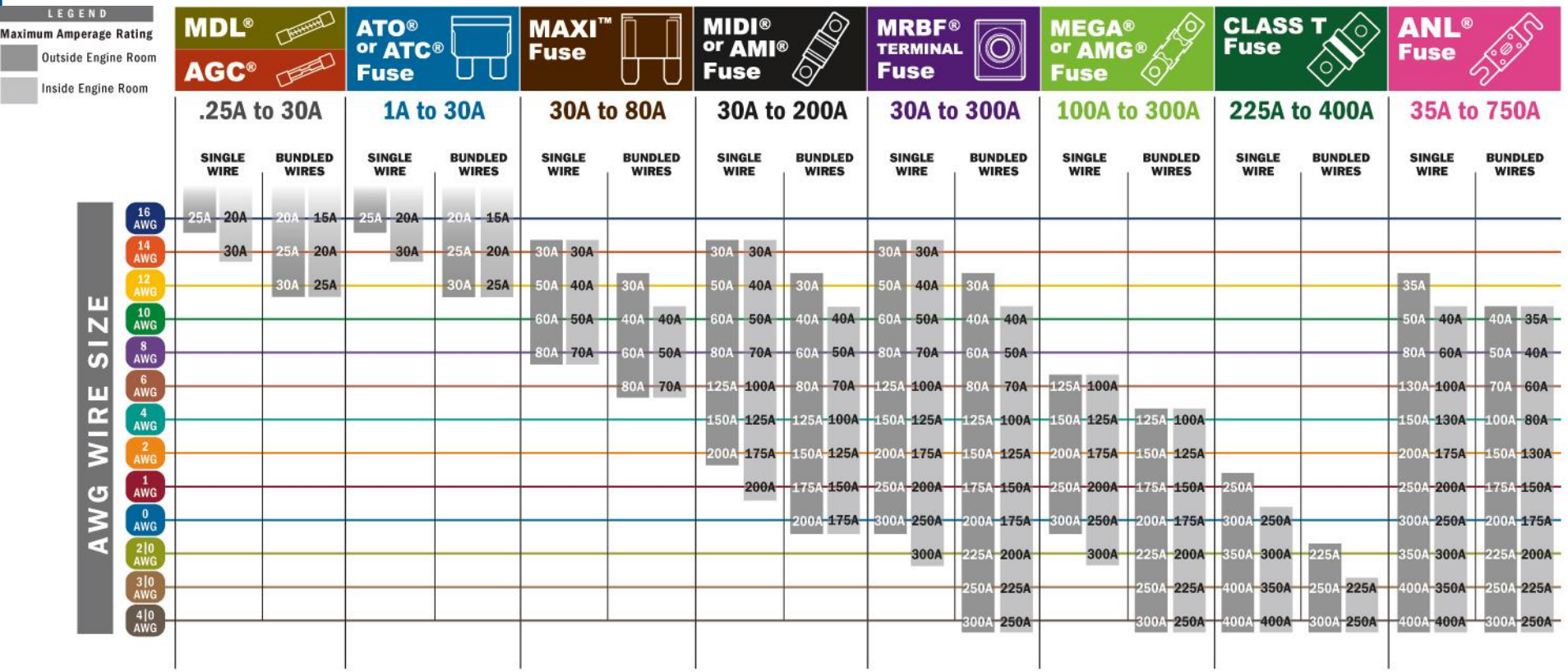
Fuse Selection Guide



Additional replacement fuses available from Blue Sea Systems:

- GMA® Fuse — 1A to 10A
- AGA® Fuse — 20A
- ATM® Fuse — 5A to 30A

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Fusing Demo #1:
Fuse located near battery

Fusing Demo #2:
Fuse close to appliance

Fusing Demo #3:
Two wire sizes, fuse for each wire

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Fusing Demo #4:
Two wire sizes, large fuse only

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Fuse & Circuit Breaker Installation Tips

- Size to handle load and wire gauge
  - IMPORTANT: Avoid nuisance tripping
- Disconnect “turn off” load before swapping fuse
- Use cover to protect positive (energized) post
- Carry spare fuse near fuse holder
- Choose thermal breaker when:
  - Recommended by manufacturer
  - Use a switch
  - Trip possibility (e.g. motors: water pump, windlass, etc…)

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Troubleshooting

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Trouble Shooting Theory

- Requires a basic understanding of the circuit
- What are the components that could fail?
- Requires a logical and methodical approach
- It is usually NOT the device that has failed

Eliminate the Obvious

- It is the battery switch turned on?
- Is the main breaker panel switch turned on?
- Is the branch breaker to the device turned on?
- Is the switch on the device itself turned on?

Trouble Shooting Theory

- If no luck, start working through the circuit
- Typical problems on boats:
  - No power or not enough power to device
  - Battery voltage has dropped too low
  - Corrosion on terminal or connector
  - Broken wire or loose connector
  - Short circuit from chafed wire
  - Blown fuse or breaker - fuse may be hidden
- Use your meter to test the entire circuit **in sequence**

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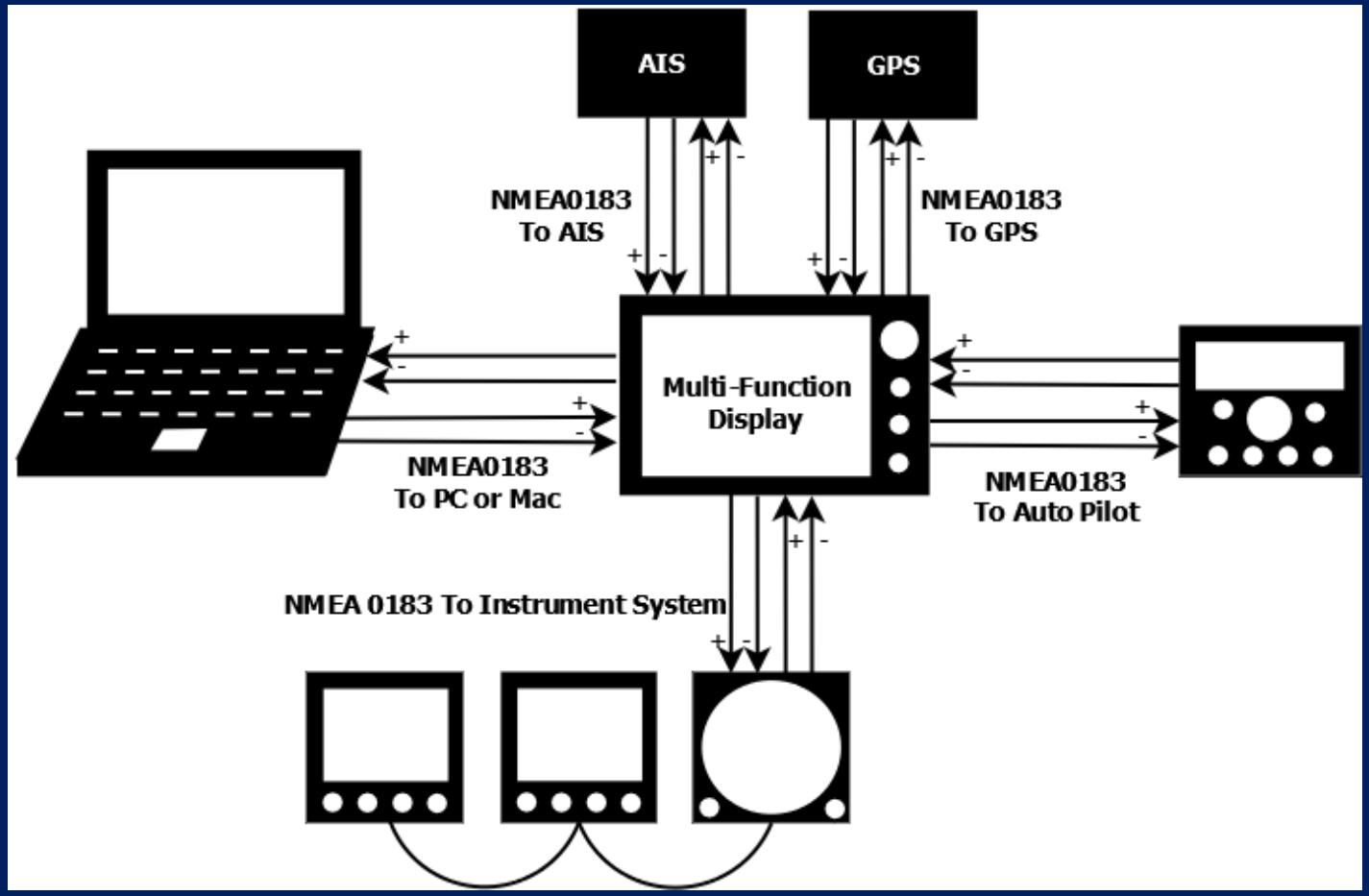
Typical NMEA 0183 Network



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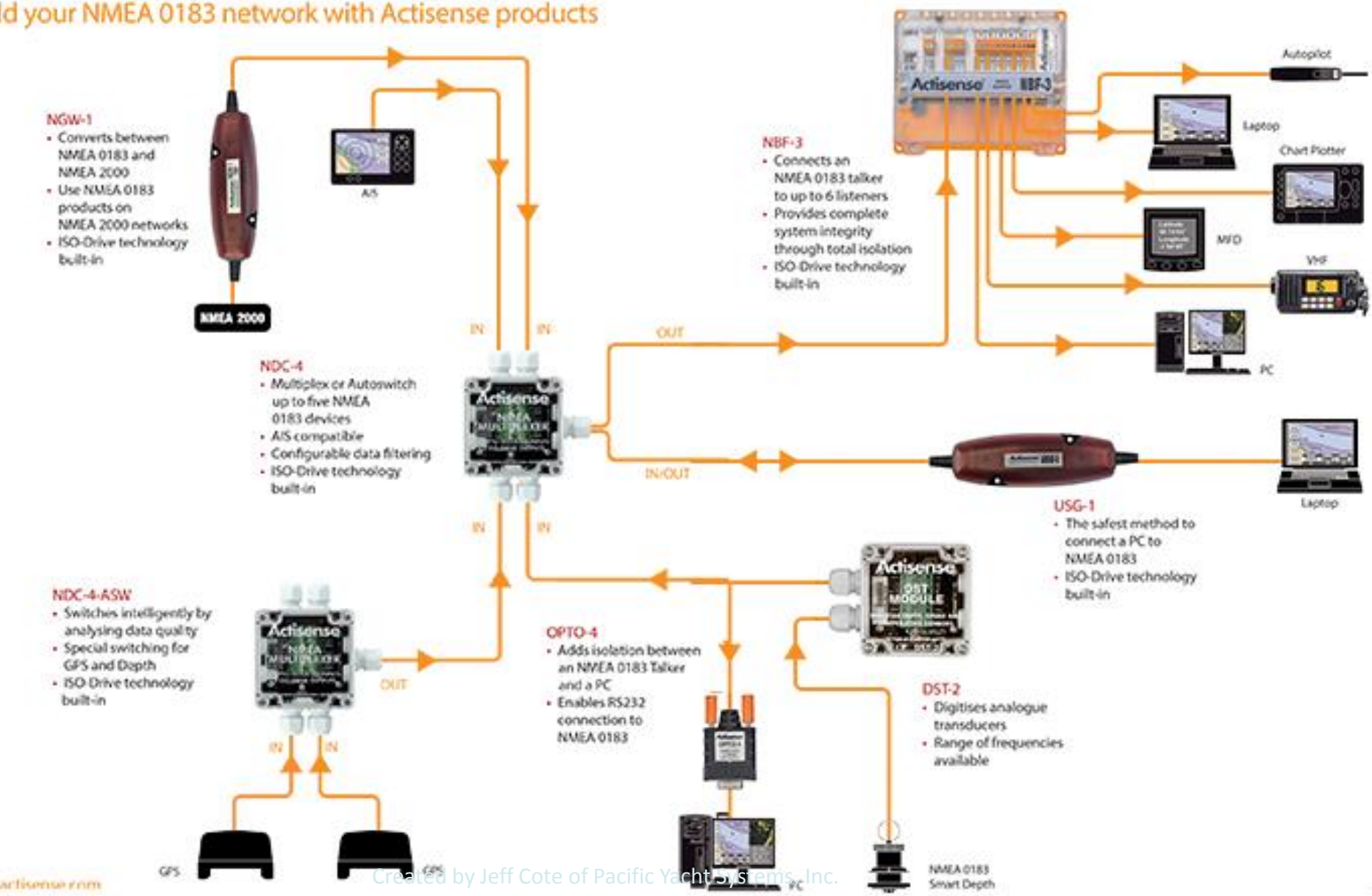
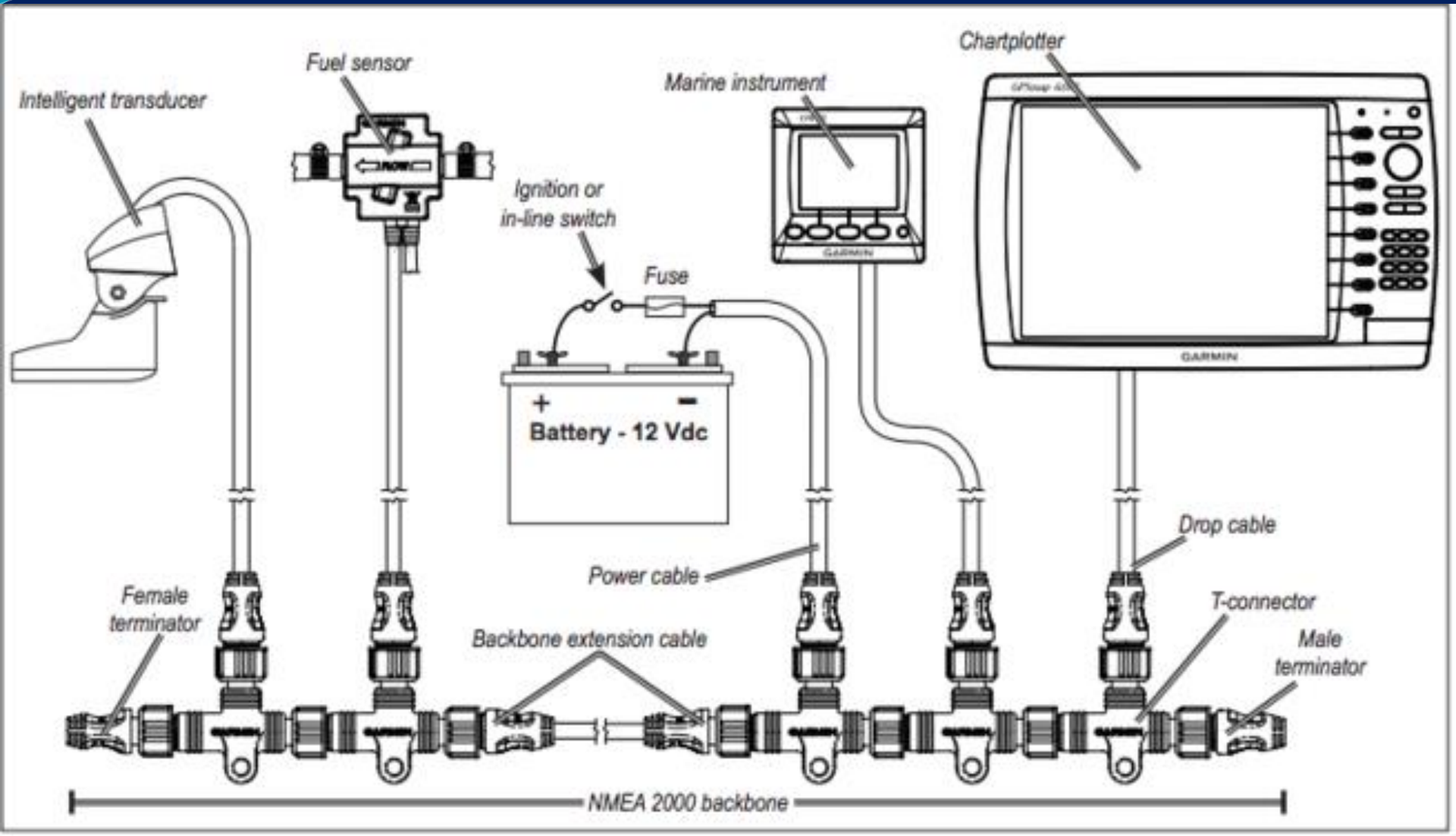
ACTISENSE NMEA 0183 NETWORK DIAGRAM

Build your NMEA 0183 network with Actisense products



N2K Network Diagram



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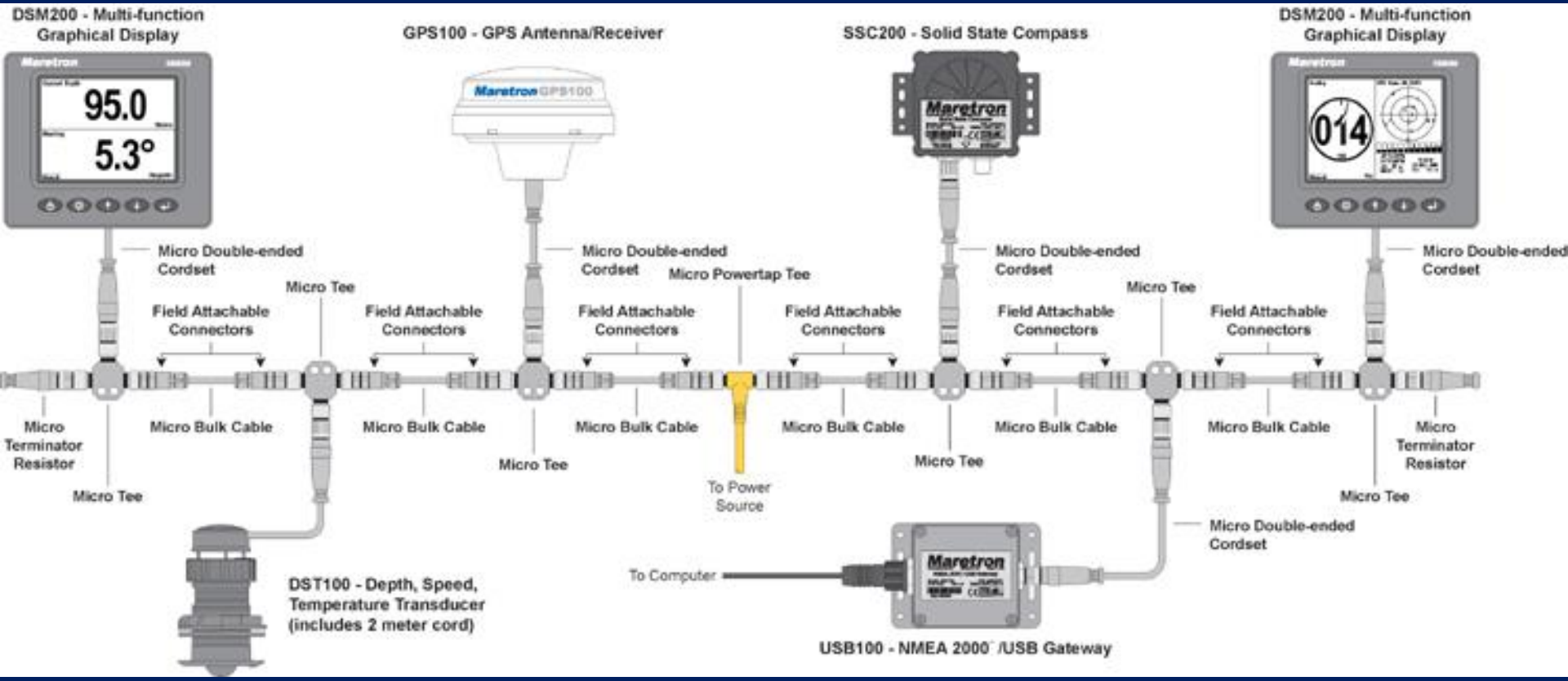
N2K Maretron Example



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High-Level
N2K & Ethernet Connectivity

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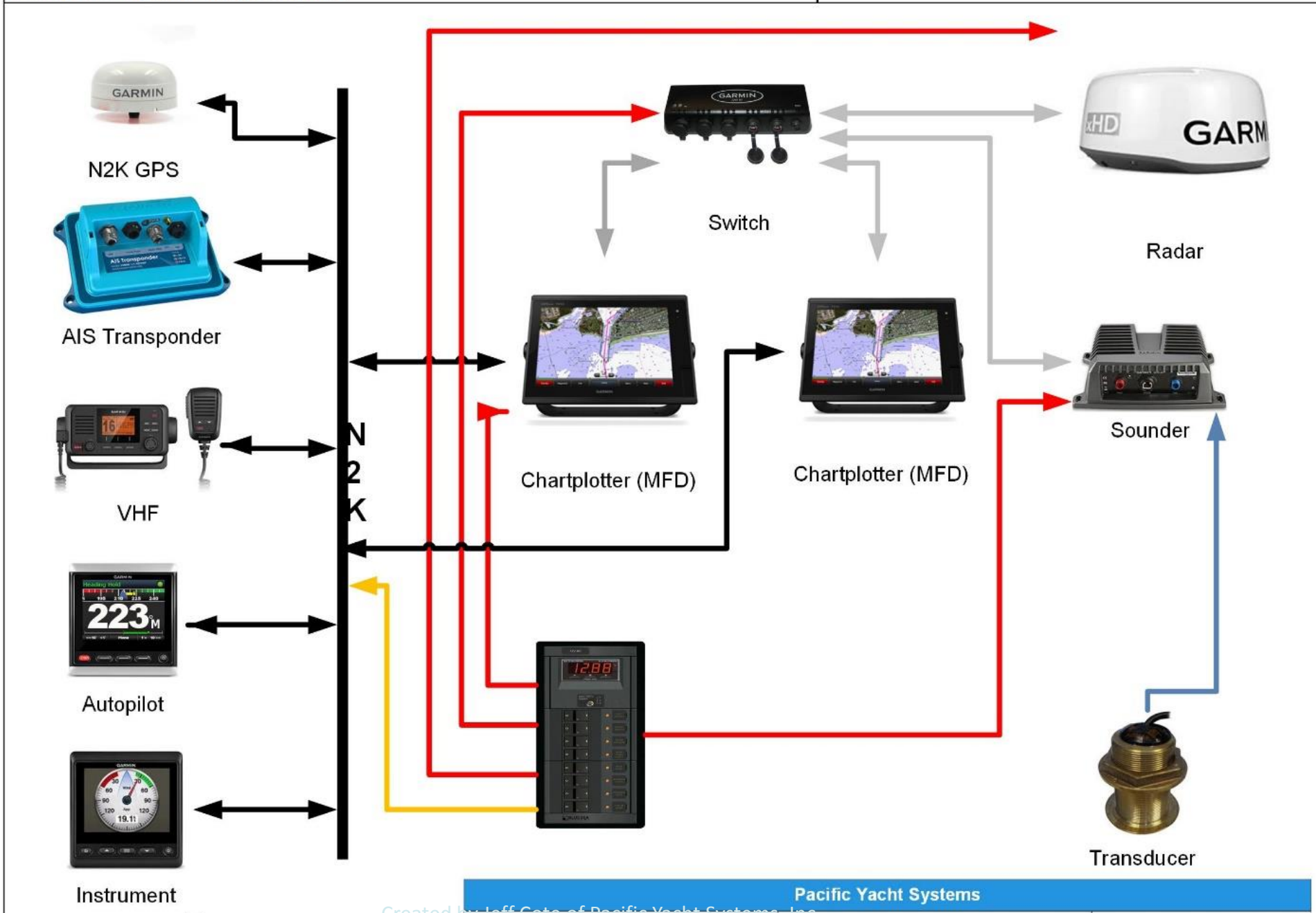
Conceptual Diagram: Chartplotter (MFD)



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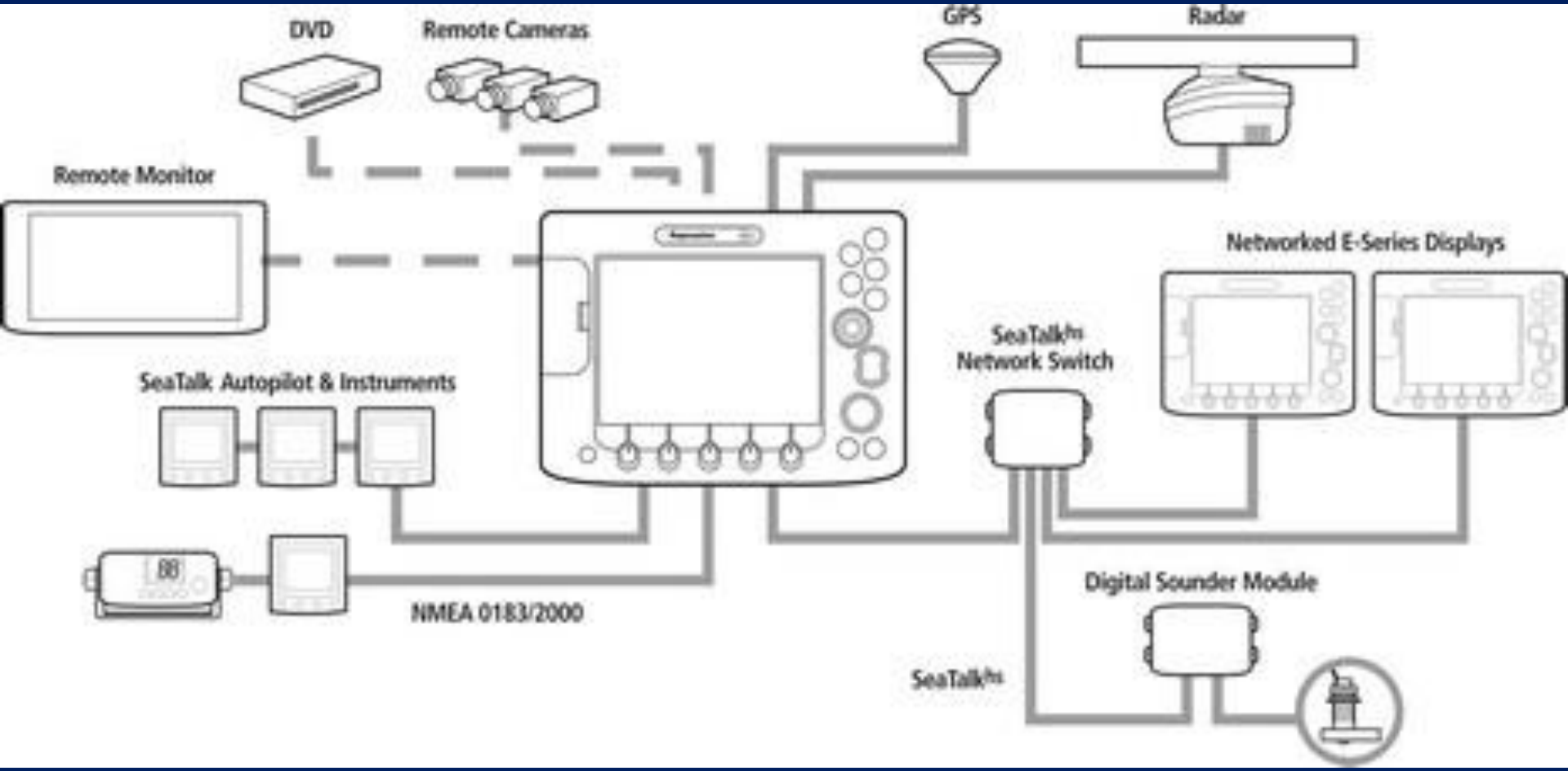
Mid-Size Nav System
Raymarine Classic



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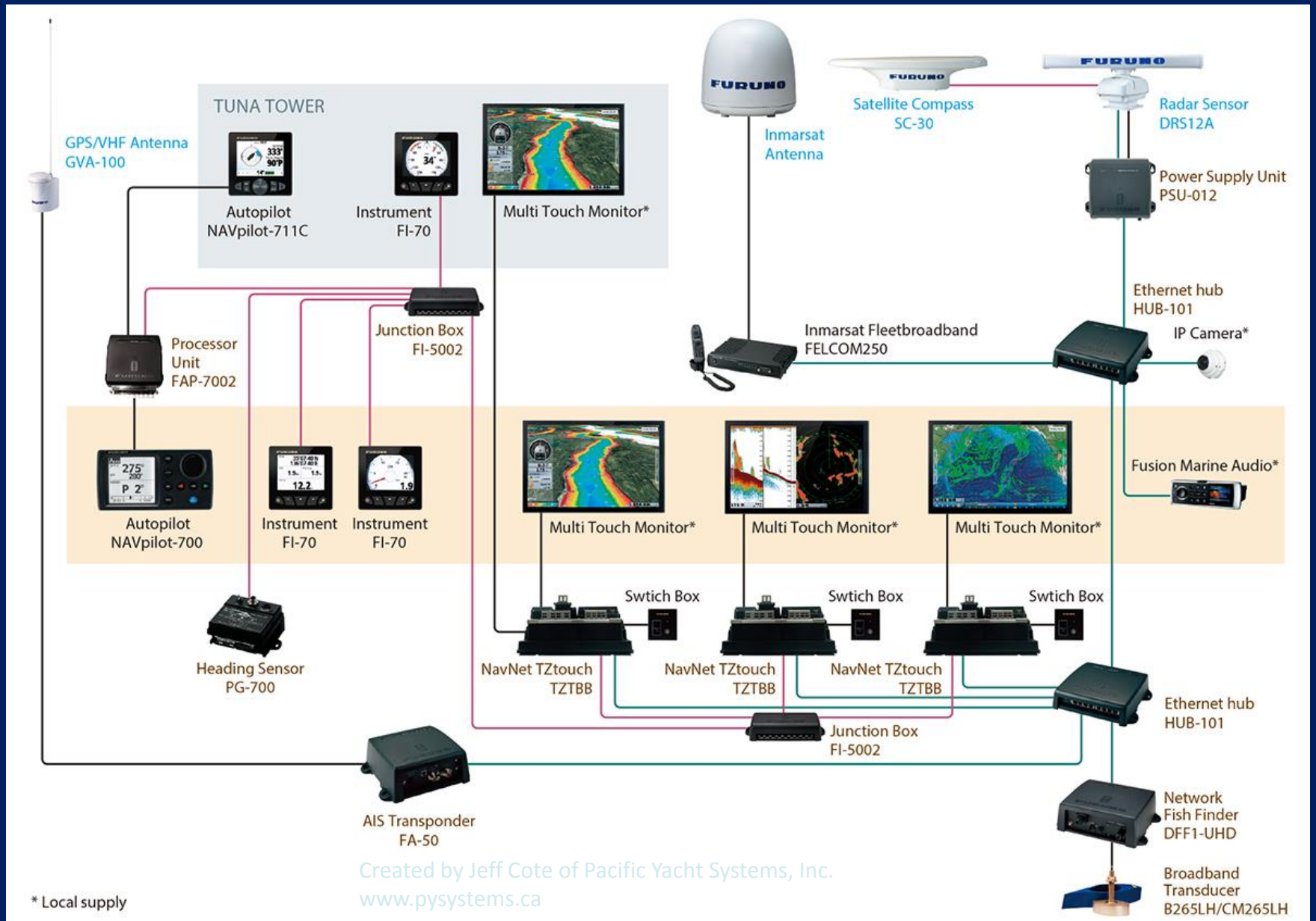
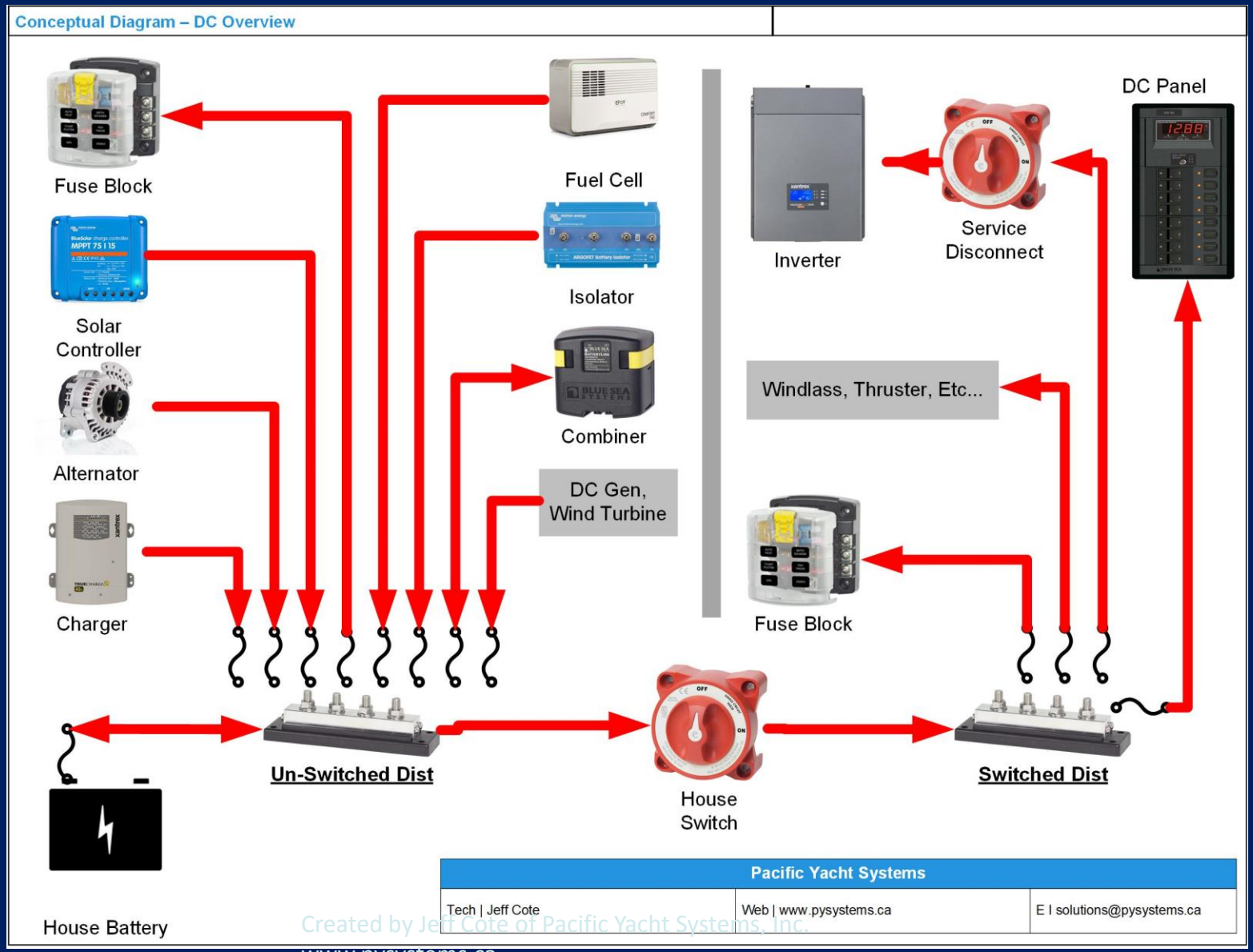
Mid-Size Nav System
Garmin Example

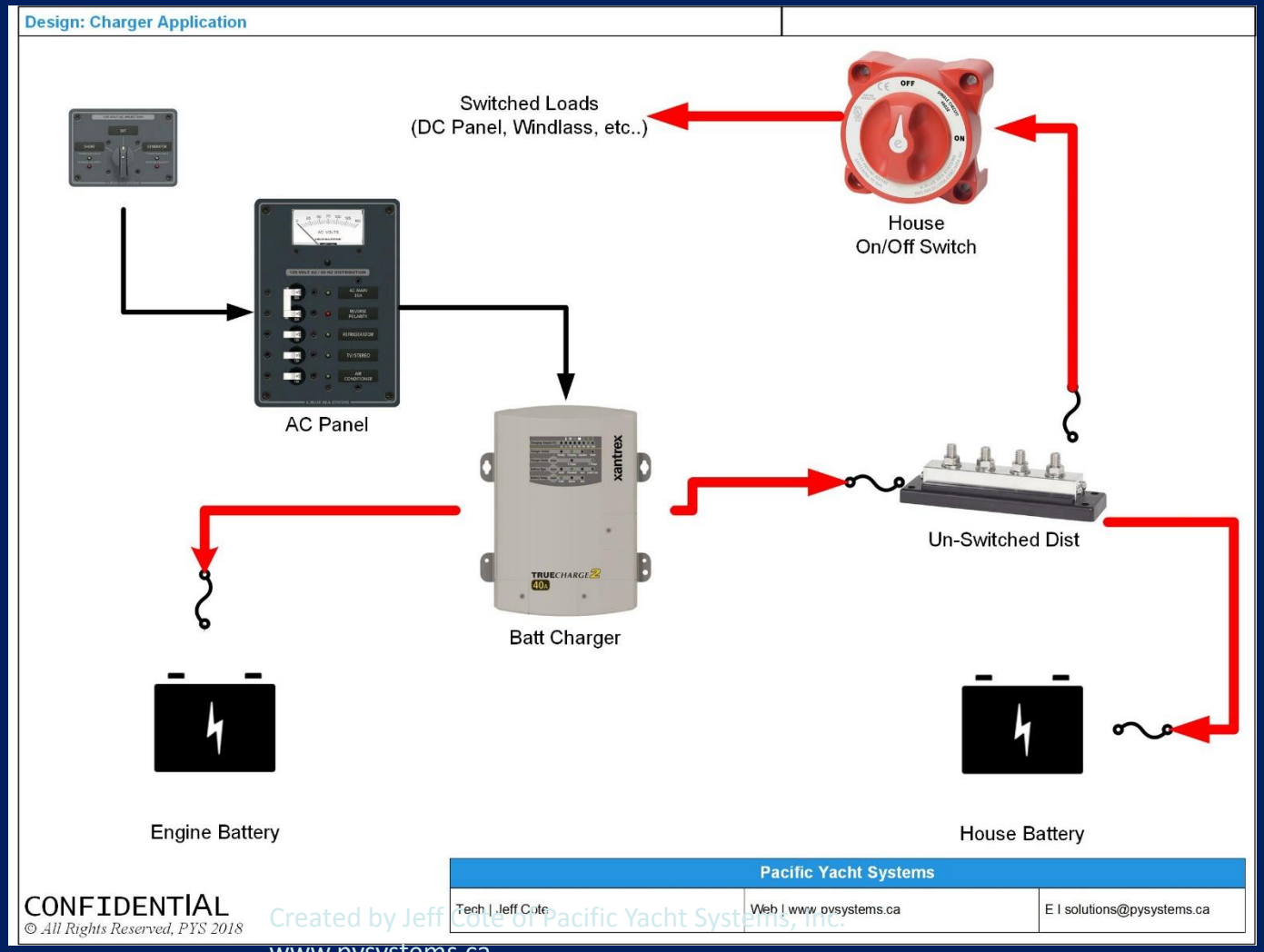
Large Nav System Furuno Example



DC Conceptual Overview



Charger Conceptual Diagram



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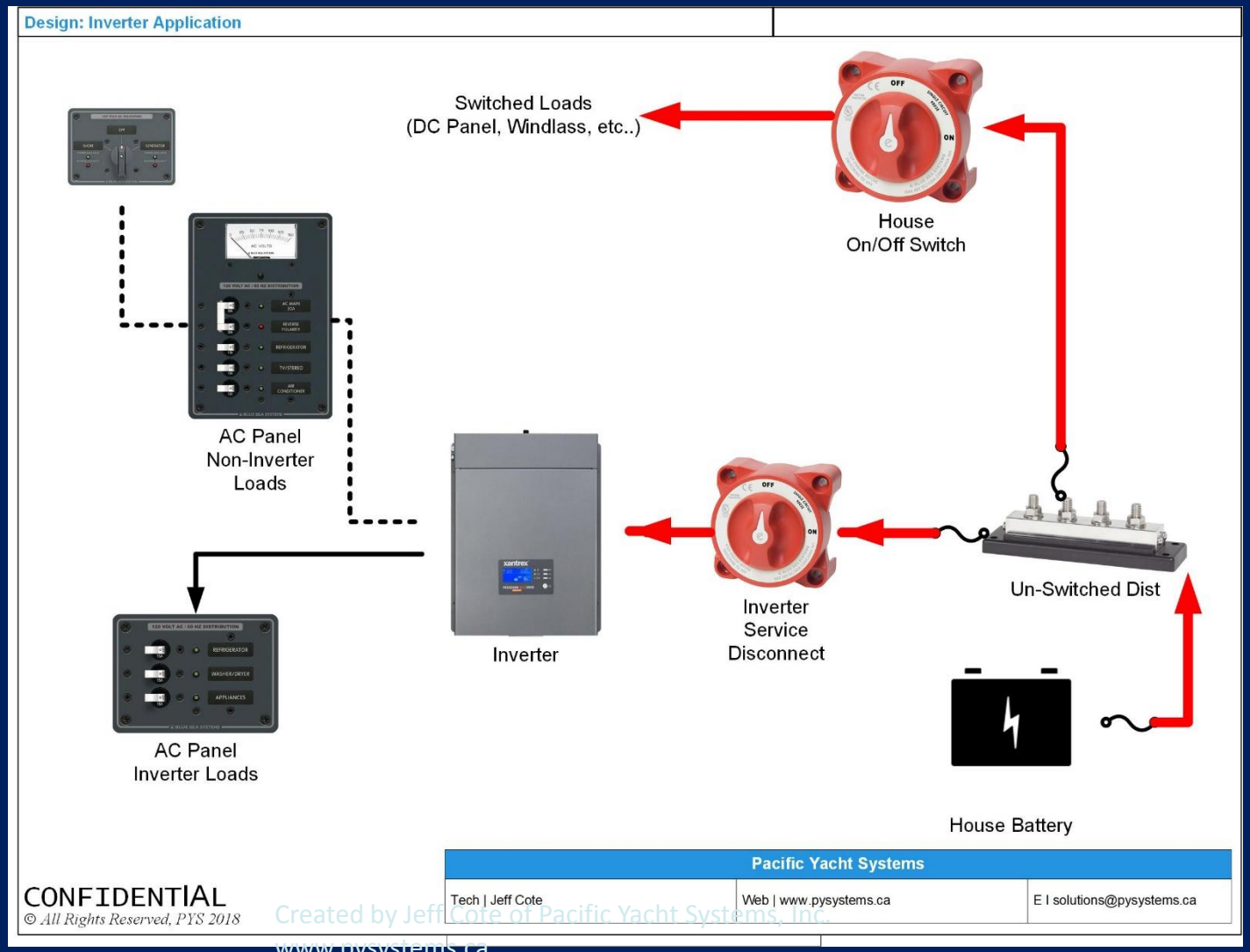
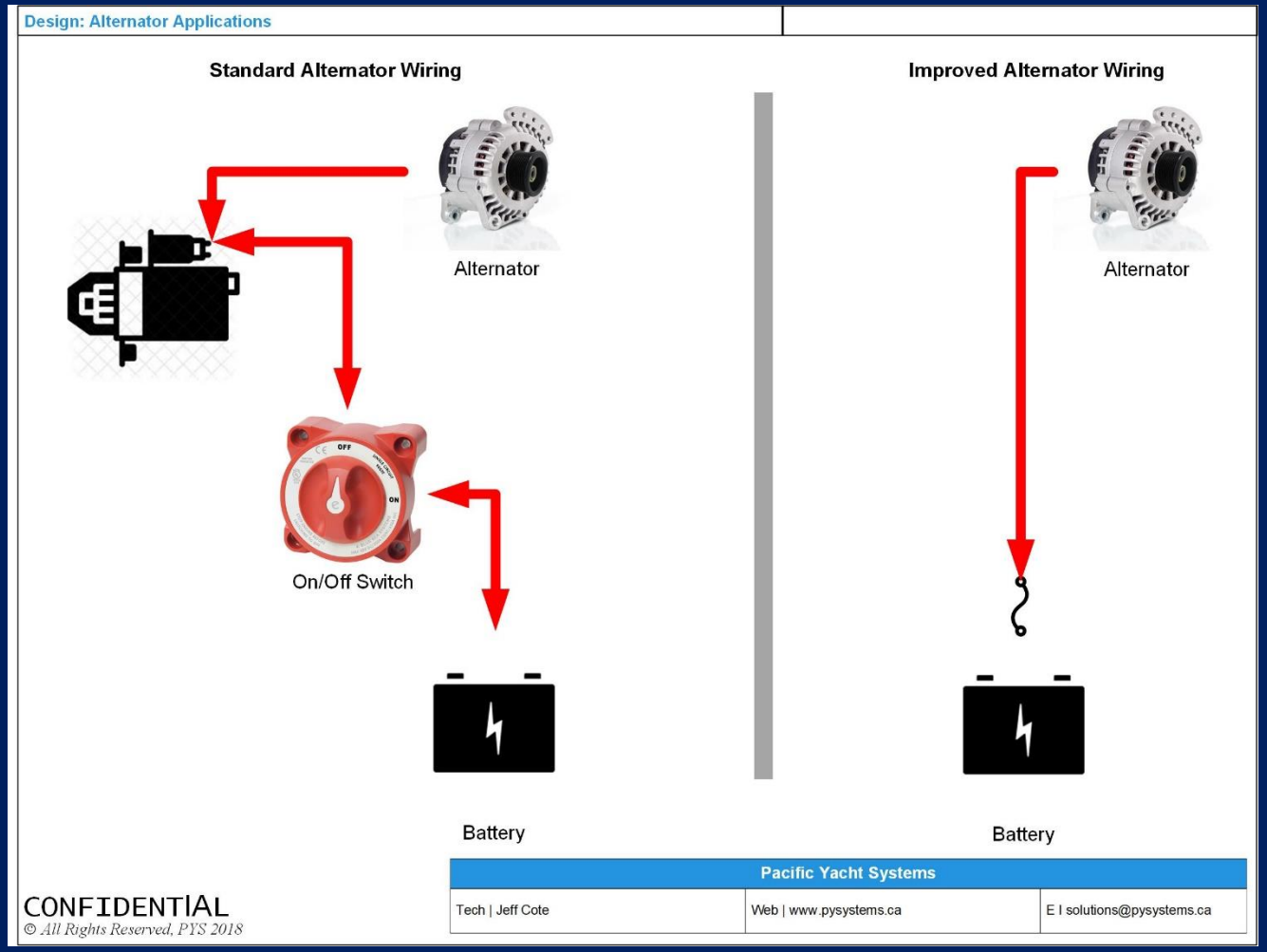
Inverter & Inverter/Charger Conceptual Diagram



Alternator Conceptual Diagram



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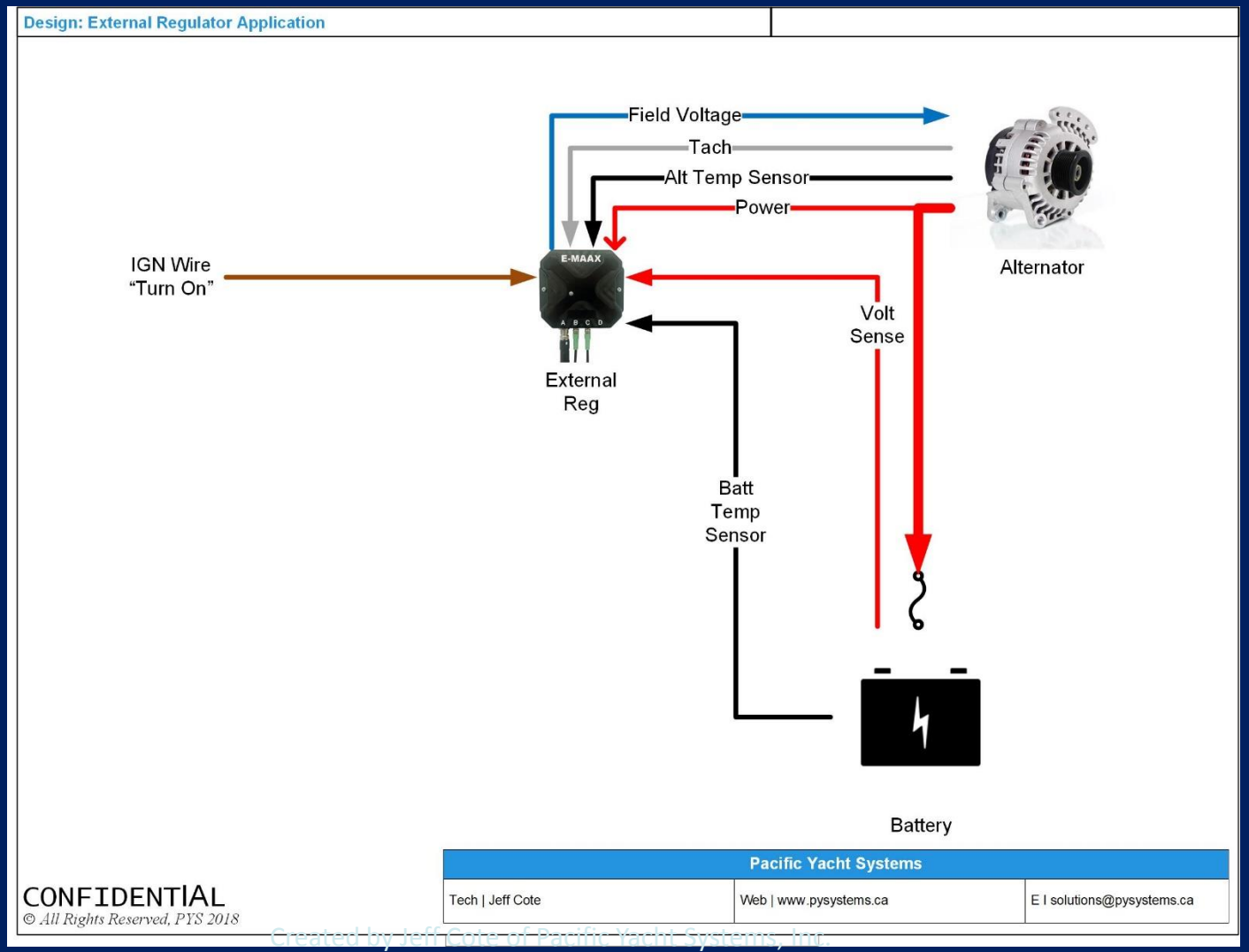
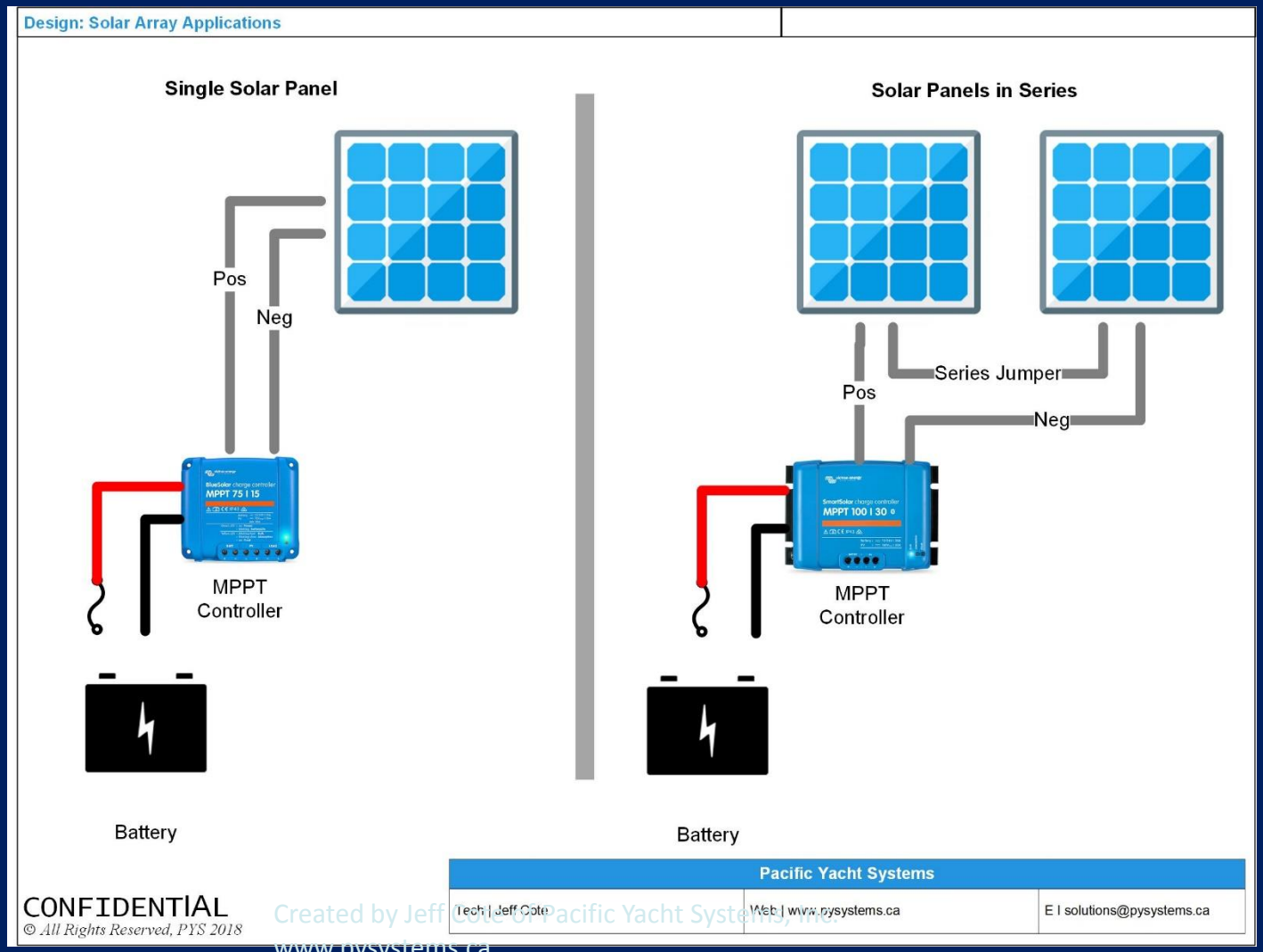
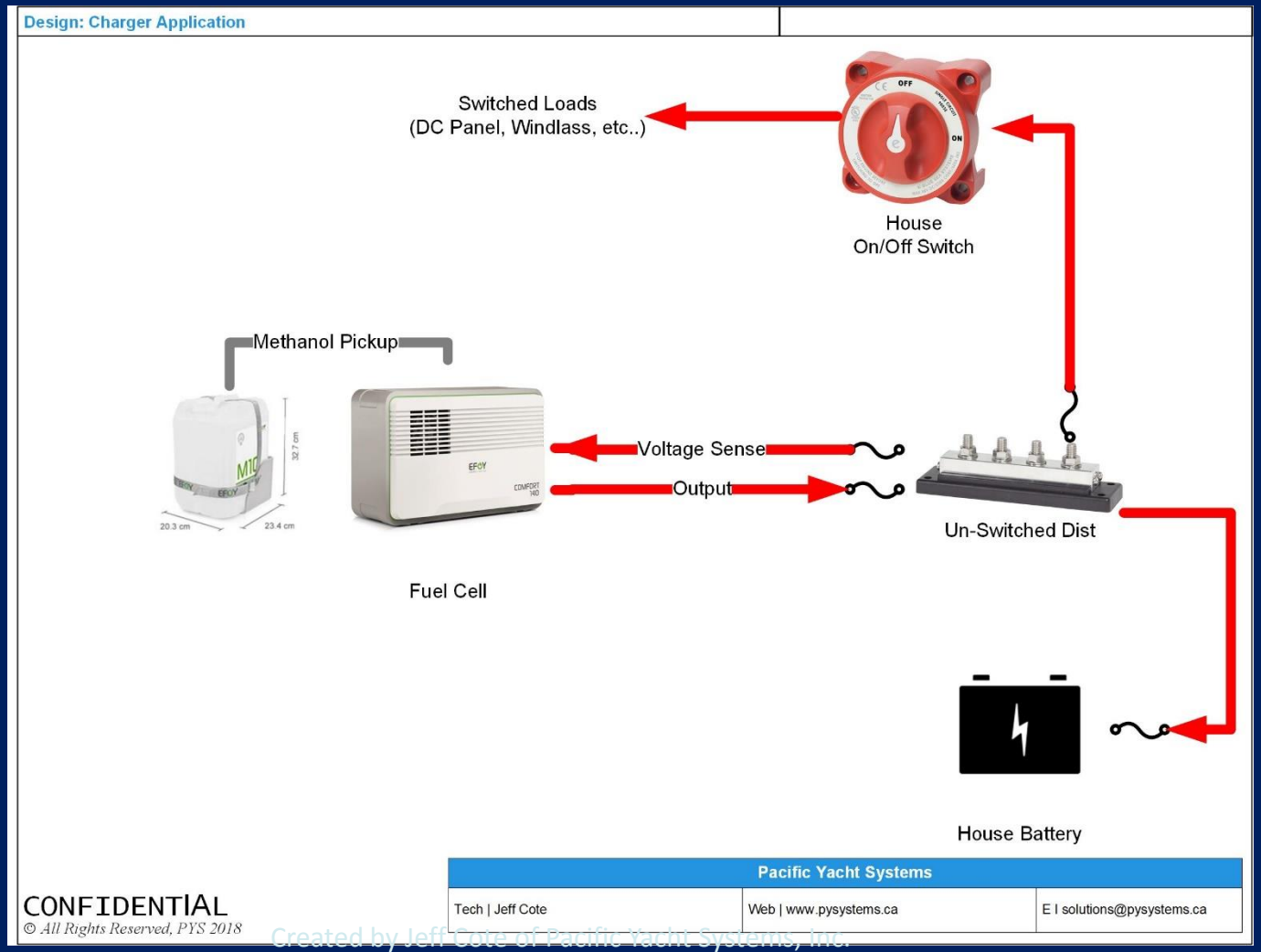
External Regulator Conceptual Diagram



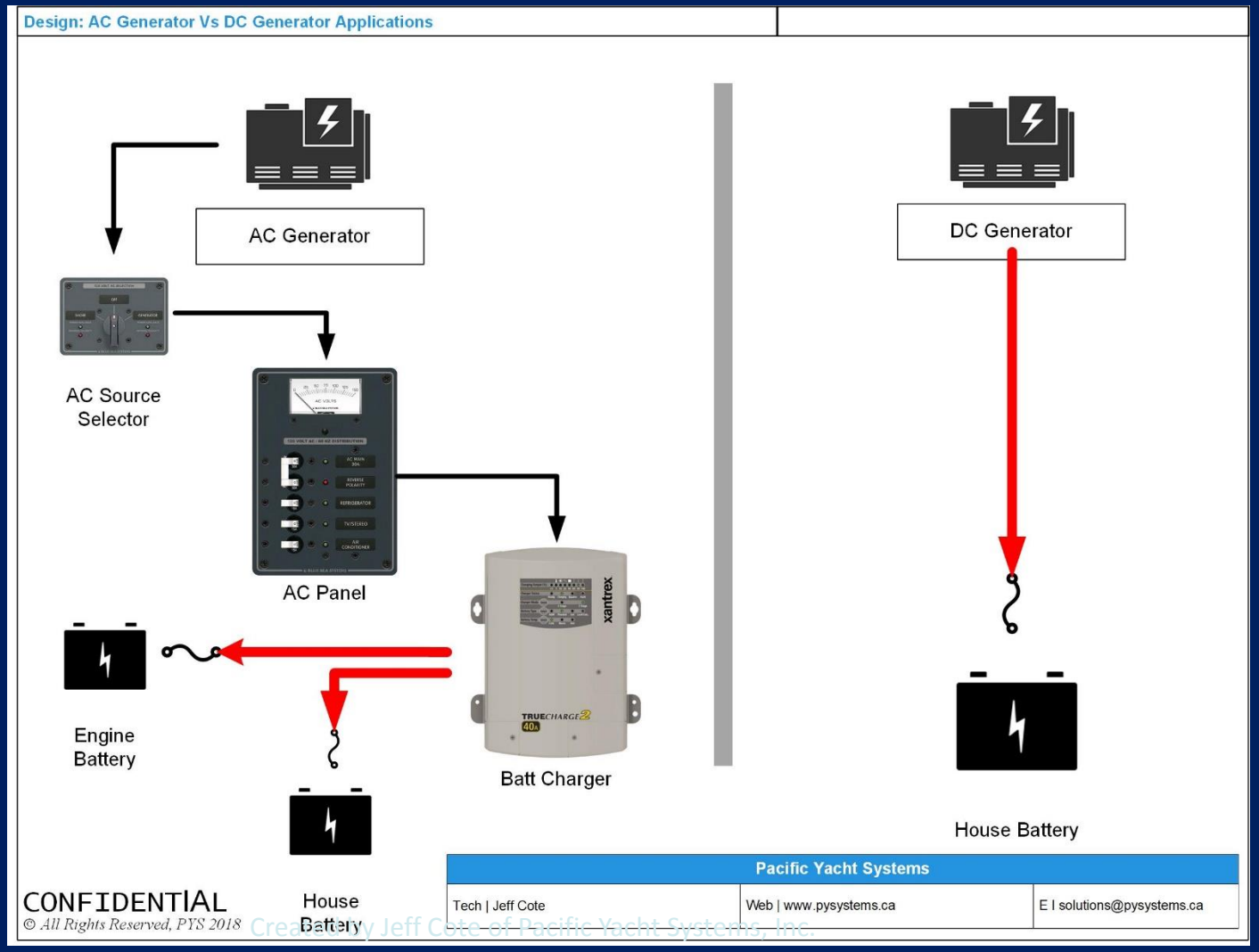
Solar Conceptual Diagram



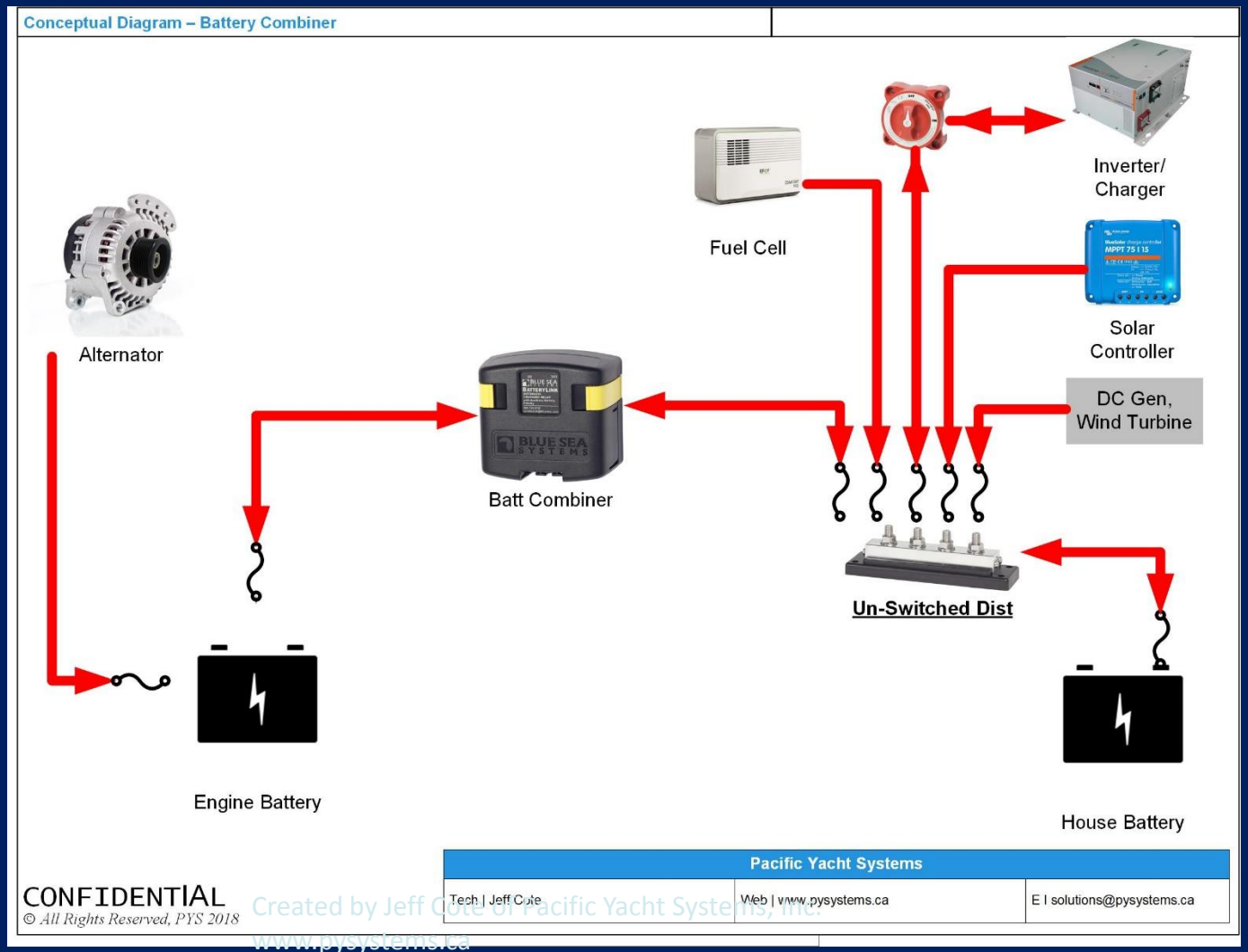
Methanol Fuel Cell Conceptual Diagram



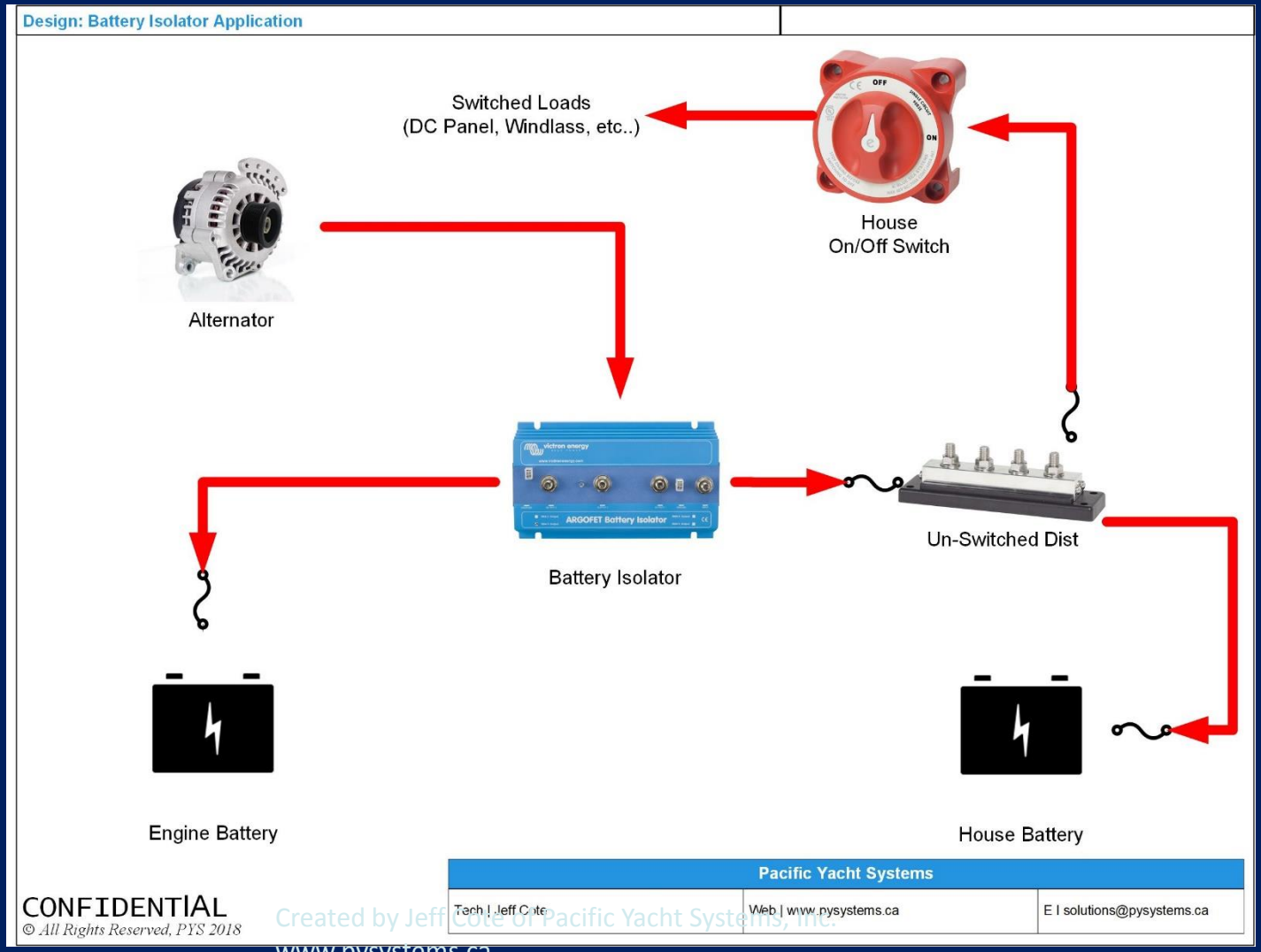
AC Gen & DC Gen Conceptual Diagram



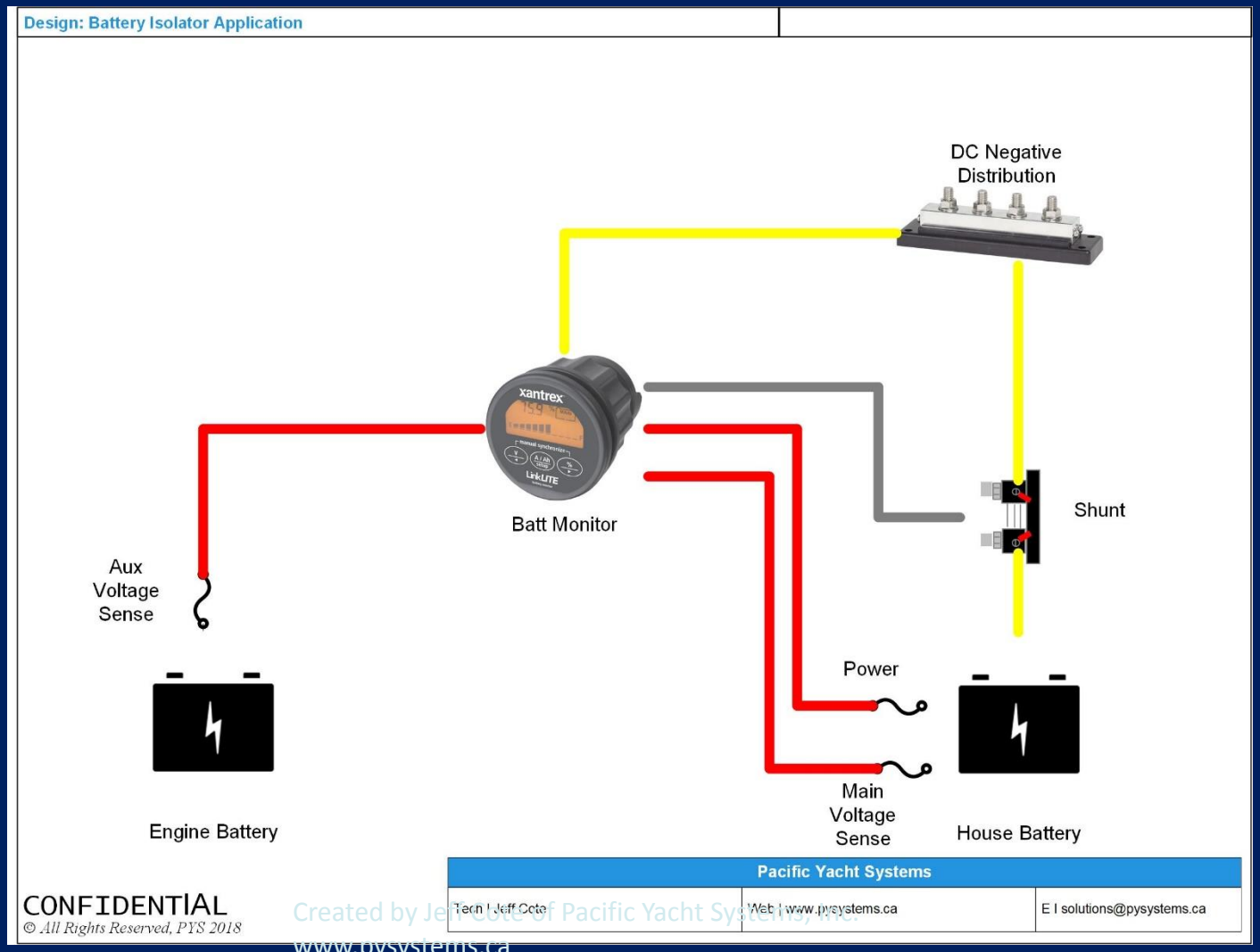
Battery Combiner Conceptual Diagram



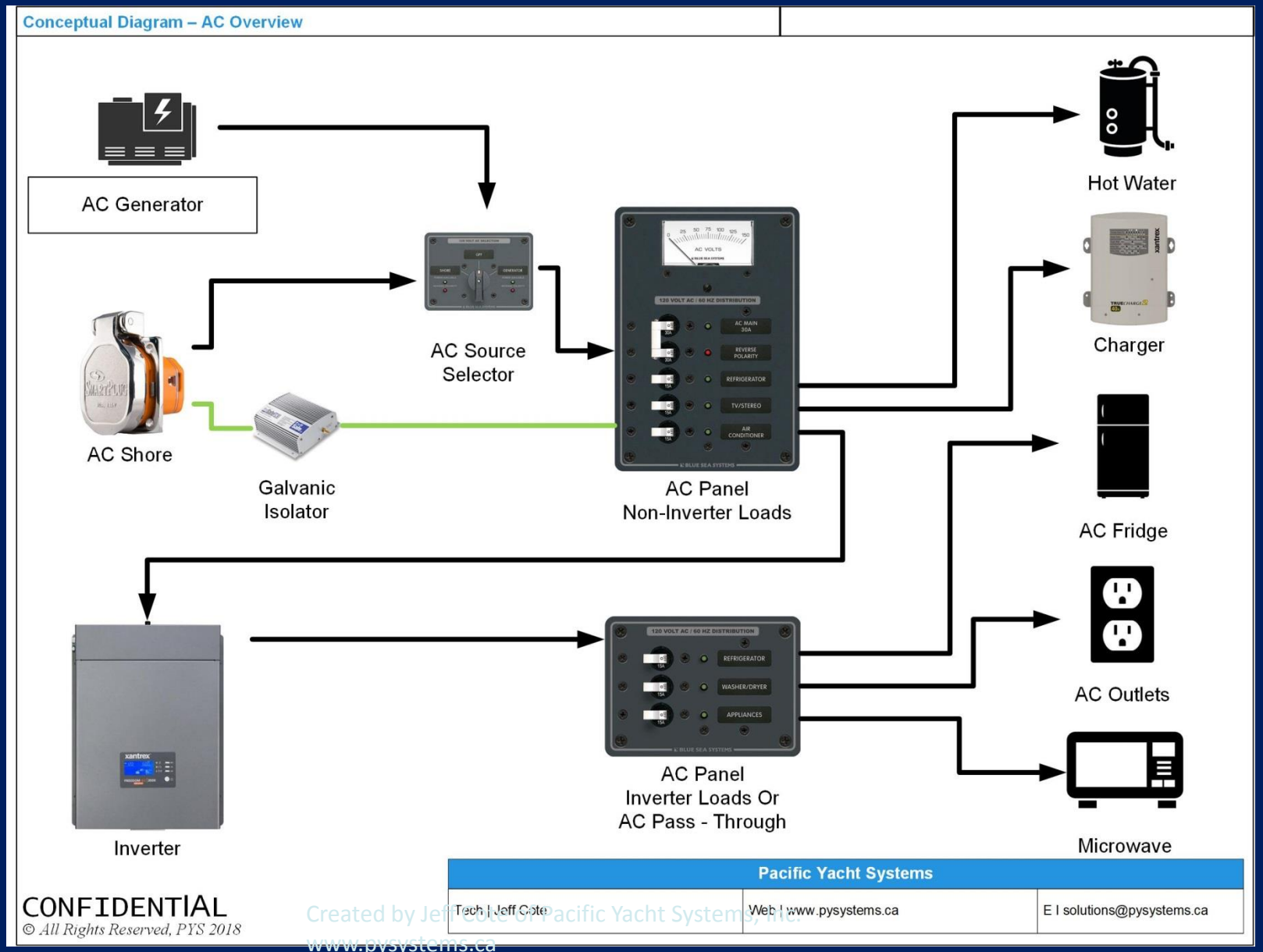
Battery Isolator Conceptual Diagram



Battery Monitor Conceptual Diagram



AC Conceptual Diagram



Galvanic Isolator Conceptual Diagram