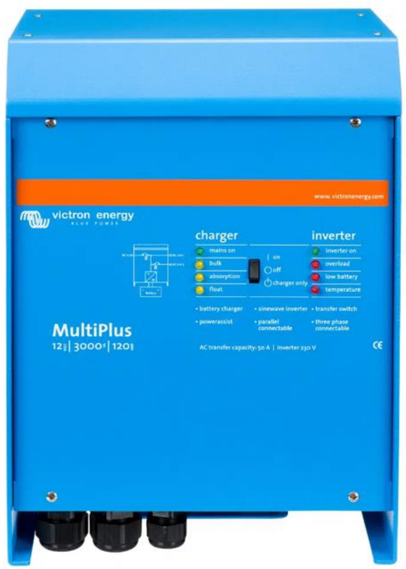
Electrical Systems

Understanding and Troubleshooting

Thursday (Day 1)



A Lot to Cover

- AC & DC
- Phase & Voltage
- Amps/Volts/Hertz/Watts/Power/??
- Batteries & Generators
- Shore Power & Ship's Power
- Galvanic Corrosion
- Regulations and Requirements
- Best Engineering Practices
- Safety while Operating & Repairing
- Tools You'll Need
- Where to Buy the Right Parts
- When to Call For Help

A Bit About Me

- Lifetime Boater & Long-Distance Cruiser
- Sportfish & Motoryacht Captain
- SAMS® Surveyor Associate
- ABYC Certified Master Technician
- Owned a Brokerage & Consulting Group
- USCG RTMC/GMDSS Task Force
- Cruising Editor of Waterway Guide™
- USCG Licensed Deck & Engine Room

Another Day at the Office

This Morning's Syllabus

- Introductions, Expectations (Yours & Mine)
- Review of Volts, Amps, Watts, Ohms, Ah, & Hz
- Power on board: Ships' and Shore
- DC Power: Store/Use/Replace
- Researching and Planning
- Lab Time
    - Hands-On
    - Identification
    - Measurement
    - Evaluation

Introduction & Expectations
YOURS

1

2

3

4

5

6

7

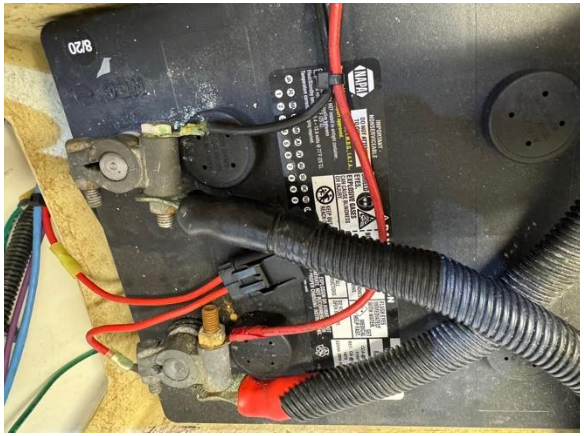
8

9

10

Introduction & Expectations
MINE

1. Review the Basics Quickly
2. Agree on our goals for the class
3. Spend time on YOUR goals
4. Get in hands-on practice (a lot!)
5. Learn from Each Other!
6. Leave with individual goals met

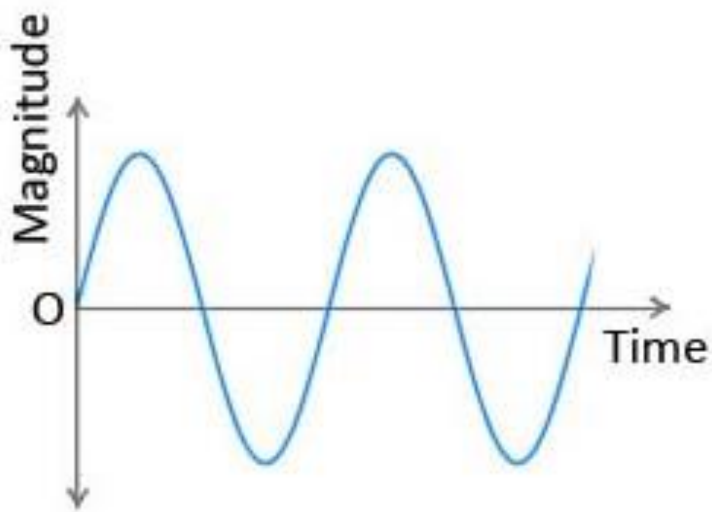


By Way of Review

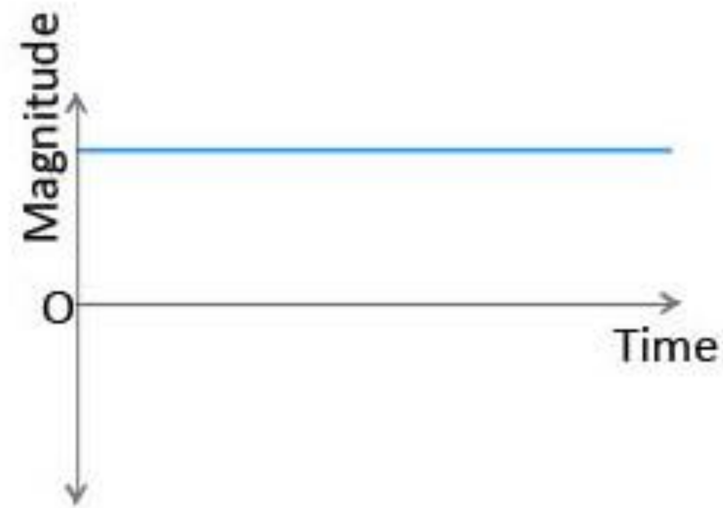
Remembering your A, B, C’s*



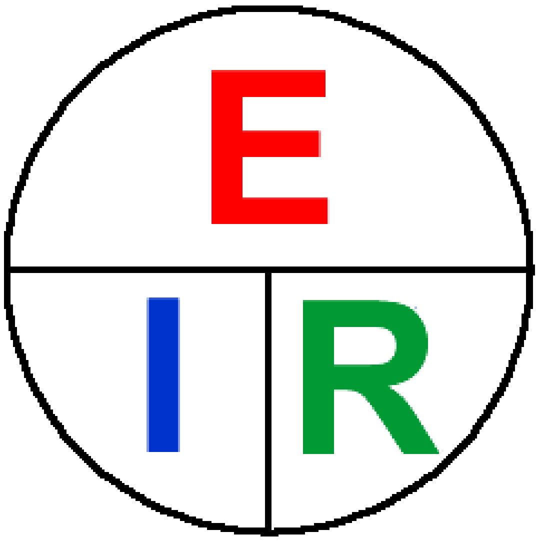
Any AC/DC Fans?



Alternating Current



Direct Current


E
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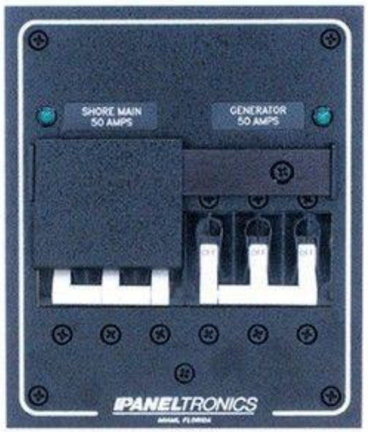
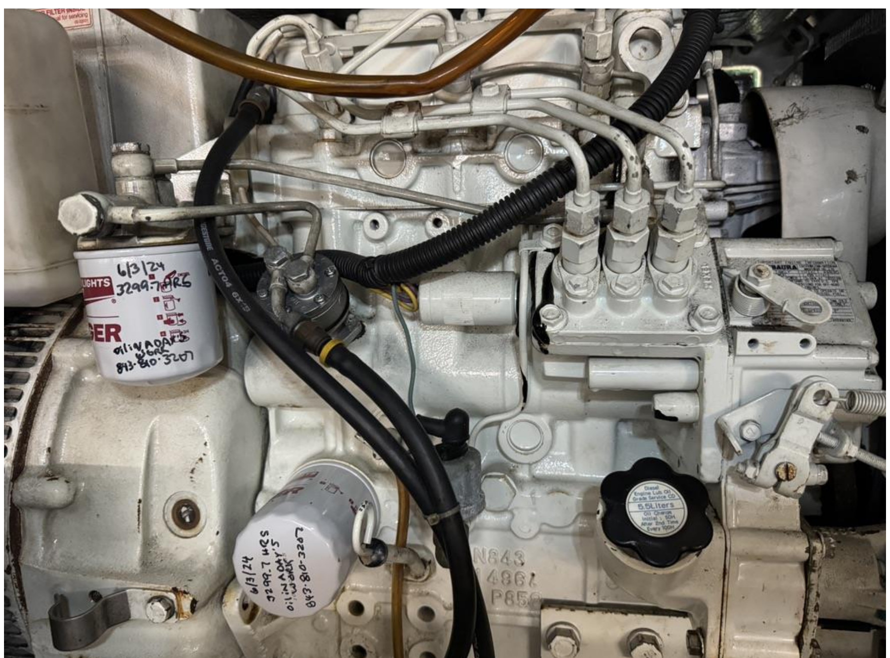
WATTS UP?

AMPS
VOLTS
WATTS

Ship to Shore





Starting and Storage Batteries

- Storing Power Electrochemically
- Chemistry and Design
- Who took my Battery Classes?
- Your Turn!

Starting Batteries

- More, Thinner Plates
- Short Bursts of Energy
- Measured in Cranking Amps

    What are CCA? MCA?

30 Sec

$0^{o}F/32^{oF}$

7.2V

Deep Cycle Batteries

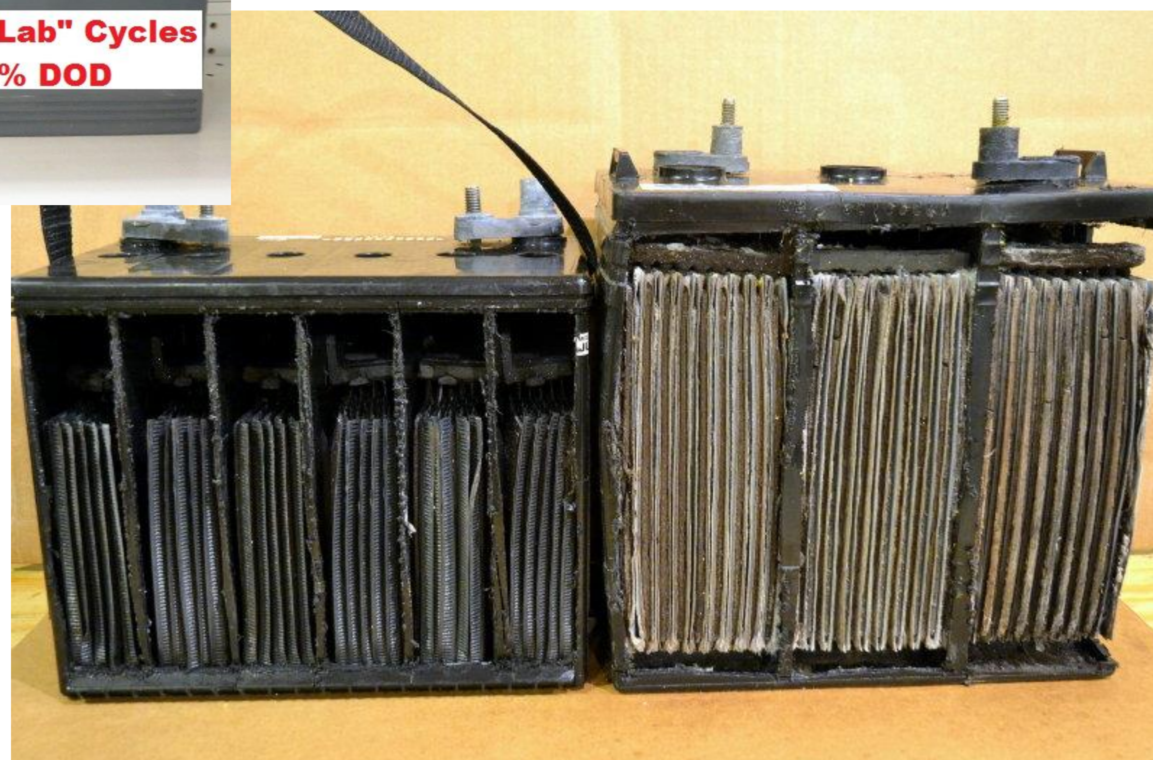
- Fewer, Thicker Plates
- Longer Output at Lower Amp Draw
- Rated in Amp Hour

So, What is an Amp Hour

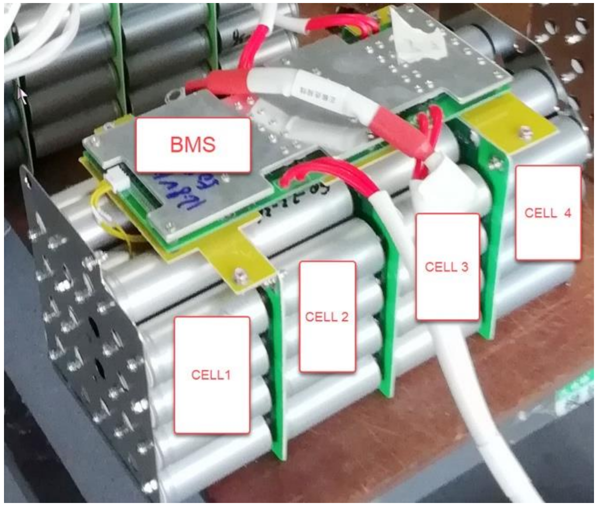
20HR 77^{o}F
5% 10.75

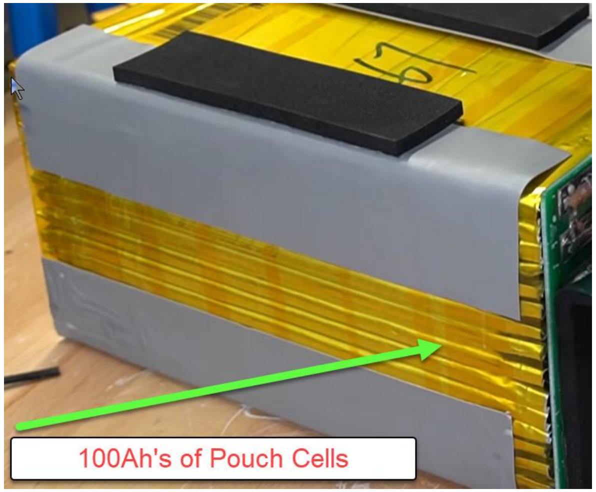
Marketing Fails

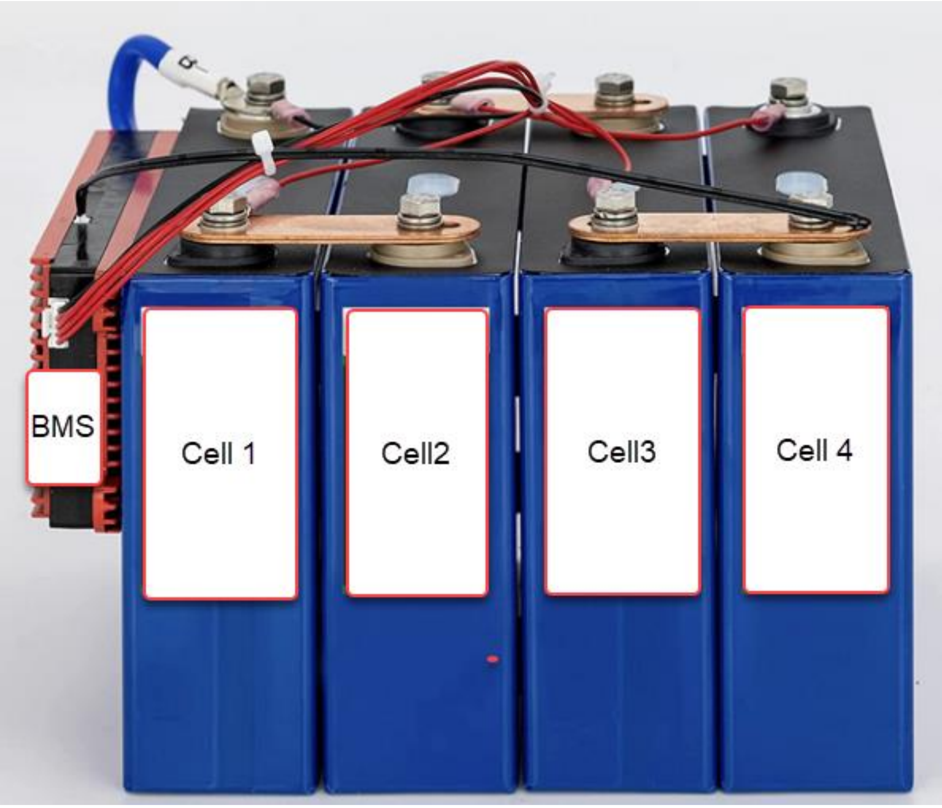
There is NO SUCH. THING as a Dual Purpose Battery!



Inside an LiFePO4 Battery







Breaking it Down

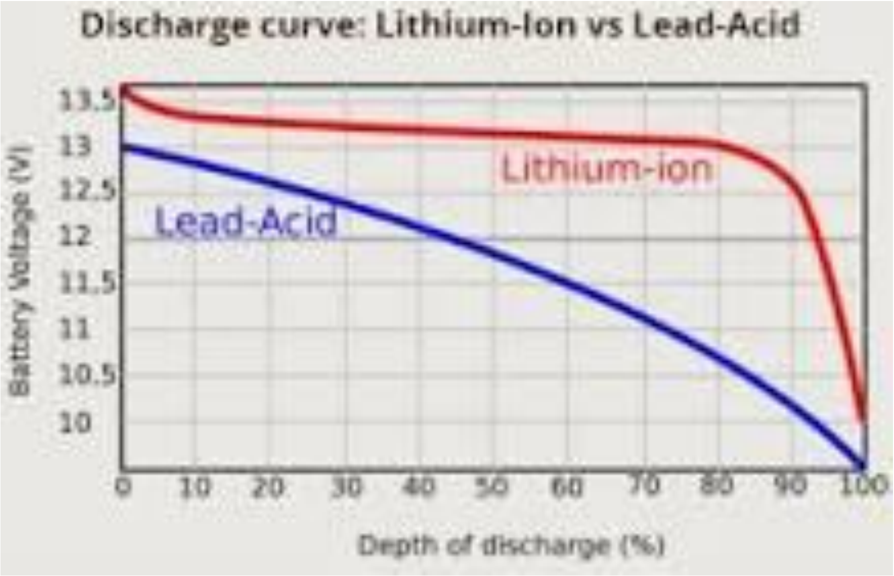
- Cell Architecture & Construction
- Manufacturing Quality
- Sourcing
- Drop-In*, External BMS Modules, DIY
- Marketing vs Engineering
- Safety Issues & Fear Mongering
- Making the Move to Lithium Ion Batteries

Marketing Language:
"Drop-in replacement for sealed lead-acid batteries and can use the same charger in most cases"

**There is NO SUCH THING as a Drop-In LiFePO4 Battery*

Discharge Power Curve

- Common Lead Battery (FLA, AGM, Gel)
  - Full Charge 12.7
  - Half Charge 12.2
  - 10% Charge 11.00
- Typical LiFePO4 Battery
  - Full Charge 13.4
  - Half Charge 13.3
  - 10% Charge 13.2



Charging

Lithionics: Charge voltage should be set to 14.4V – 14.6V, equalization and temperature compensation must be disabled, and if the charger supports float mode, set it to 13.4-13.6V.

ReLion

Operational Parameters

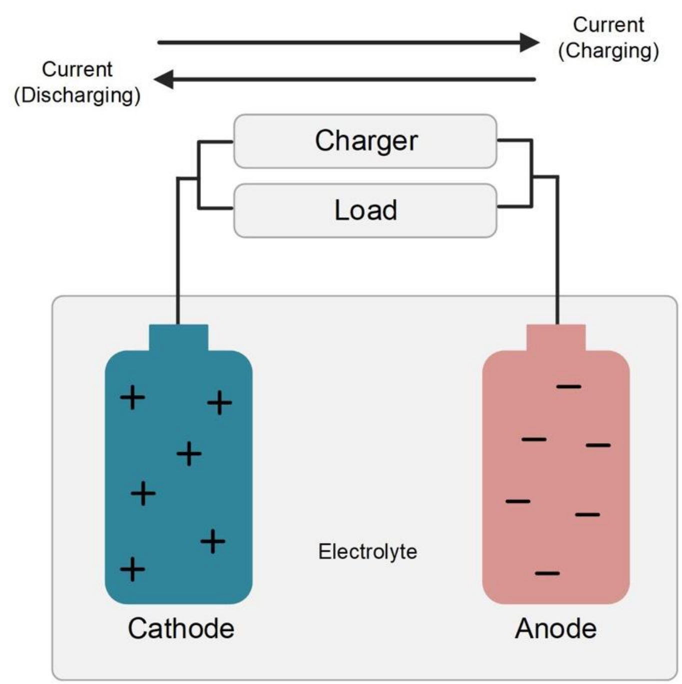
PARAMETER	12V SYSTEM	24V SYSTEM	48V SYSTEM
Bulk Voltage	14V – 14.6V	28V - 29.2V	56V - 58.4V
Absorption Voltage	14V – 14.6V	28V - 29.2V	56V - 58.4V
Absorption Time	0- 6 min	0- 6 min	0- 6 min
Float Voltage	13.3V - 13.8V	26.6V - 27.6V	53.2V - 55.2V
Low Voltage Cutoff	11V - 12V	22V - 24V	44V - 48V
High Voltage Cutoff	14.6V	29.2V	58.4V

Note: Charge current must be reduced at temperatures below 0°C (32°F). See details in Charge Temperature section.

Charging Sources

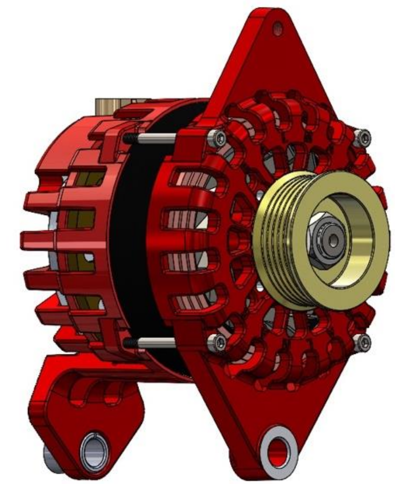
Managing and Maximizing

- Engine Alternators
- AC2DC Chargers and I/C's
- Solar & Wind
- Charge Splitting Options
- Working in the Present
- Planning for the Future



Engine Mounted Alternators

- OEM (Danger Will Robinson)
- Paths to Upgrade
- Internal and External Regulation
- Cost per kwh
- Options in the 21st Century
- Best vs Common Practices



Alternator Design

- Significant Changes in the Past 10 Years
- Higher Voltages are More Common
- Temperature Monitoring More Critical
- Advances in Regulation and Monitoring
- Real World Experiences

Modern Voltage Regulation

or

Protecting Your Investment

- Battery Chemistry
- Dual Shunt Monitoring
- Maximizing Engine Runtime
- How are YOUR Alternators Wired (poll)
- Best Practices 1988, 2010, 2024

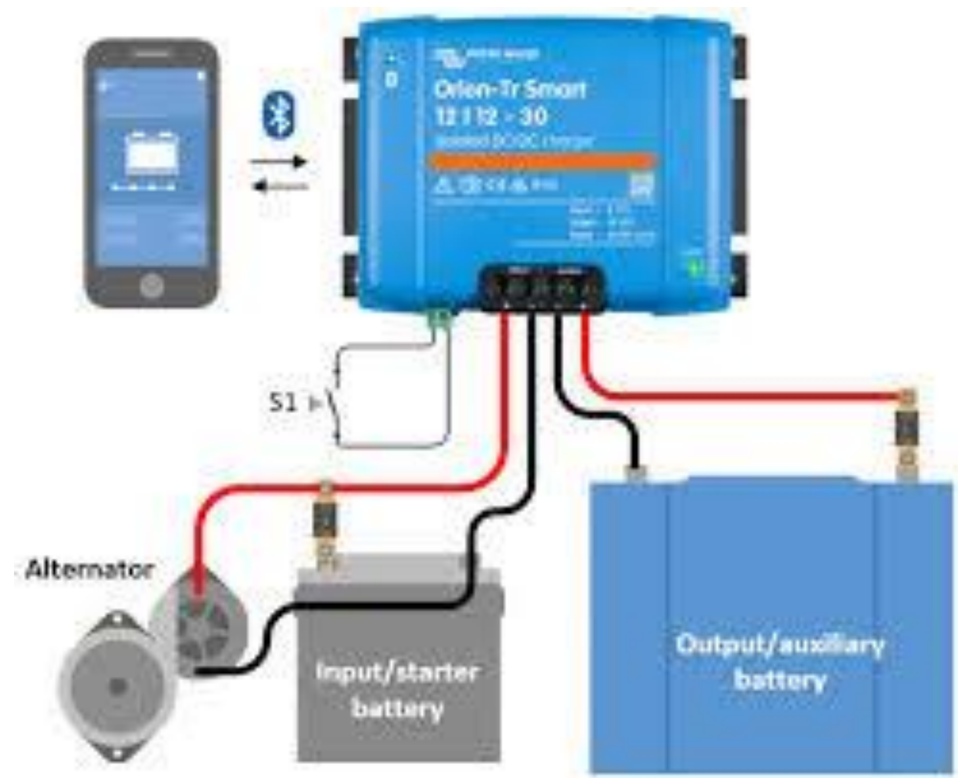
Break (coffee for the teacher)

DC2DC

Best Option for Charging Batteries with Different Chemistries

The Great Debate:

House to Starter
or
Starter to House



What it REALLY Costs

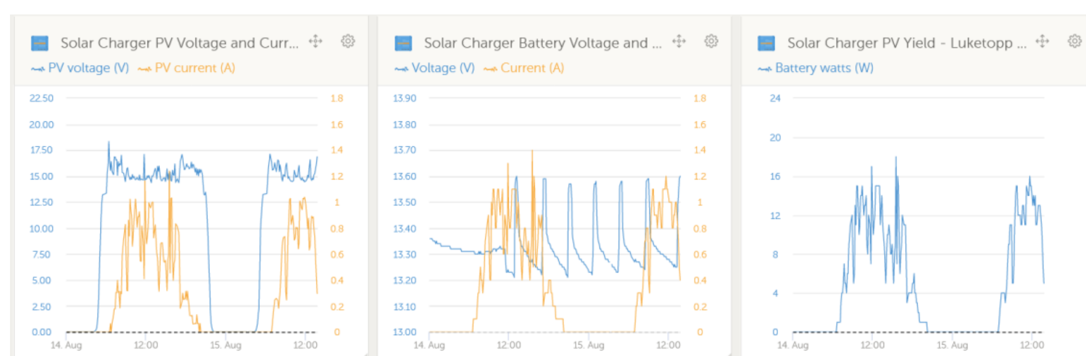
- Running a Diesel Aux Engine
  - \$3.50-\$4.50 kwh if *just* charging
- Running a Generator to an AC2DC
- Solar (the future is now)
  - Land vs Boat example (TCO)
- Wind (expensive and loud, but…)
  - Hot Water and More
- Hamster on a Treadmill

Shore Power Charging

- AC2DC (Every Boat Needs One)
- Inverter/Chargers
- Portable Chargers (More Danger Will)
- Thinking Through Your Cruising Grounds
- How I chose to do it

Making Decisions

- Battery Chemistry
- Charging Sources
- Back-up Charging
- Load Monitoring and Management



Best Practices as of Today

- Large (really LARGE) Alternator
- External Regulation with Full Monitoring
- All The Solar You Can Fit
- More Solar
- DC2DC Charger(s)
- LARGE AC2DC if needed
- Back up 15amp AC2DC 90-260 (50/60)

Digital MultiMeter

- Features
- Brands
- Probes
- Clamp-On
- Price

What to Look for in a DMM

- Fluke® on the Label
- Alternatives
- Reasons for a Good Meter
- Reasons for a Cheap Meter

$56.99

$61.90

Accuracy vs Precision

ACCURACY

Compared to a Known Value

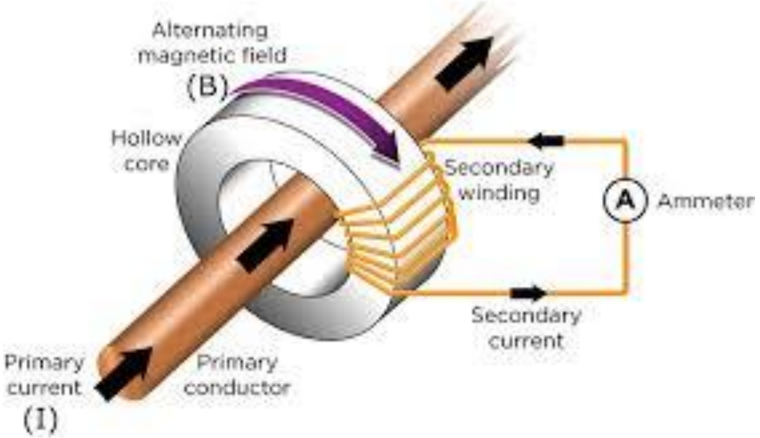
(Hit the Bull's Eye)

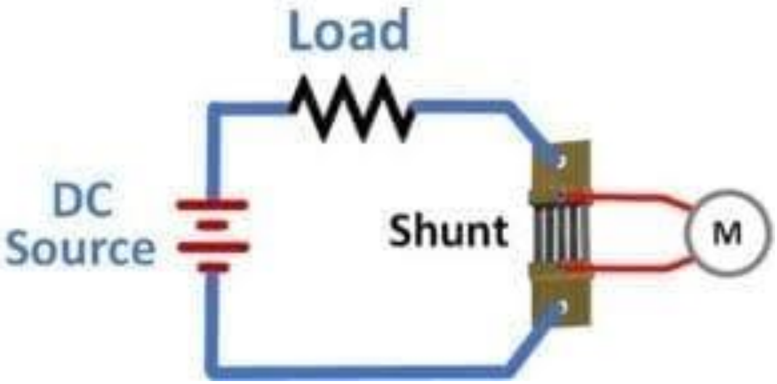
PRECISION

How Close are the Results to Each Other

(Grouping)

Shunts & Transformers





LAB TIME

- DMM’s and Other Test Tools
- Shunts & Meters
- Accuracy vs Precision
- YOUR Tool Kit
- What a Boater Needs (SPV)
- What PROS use


Lunch


PURE PROTEIN
12
21g PROTEIN
CHOCOLATE DELUXE
PURE PROTEIN

LUNCH


Coca-Cola

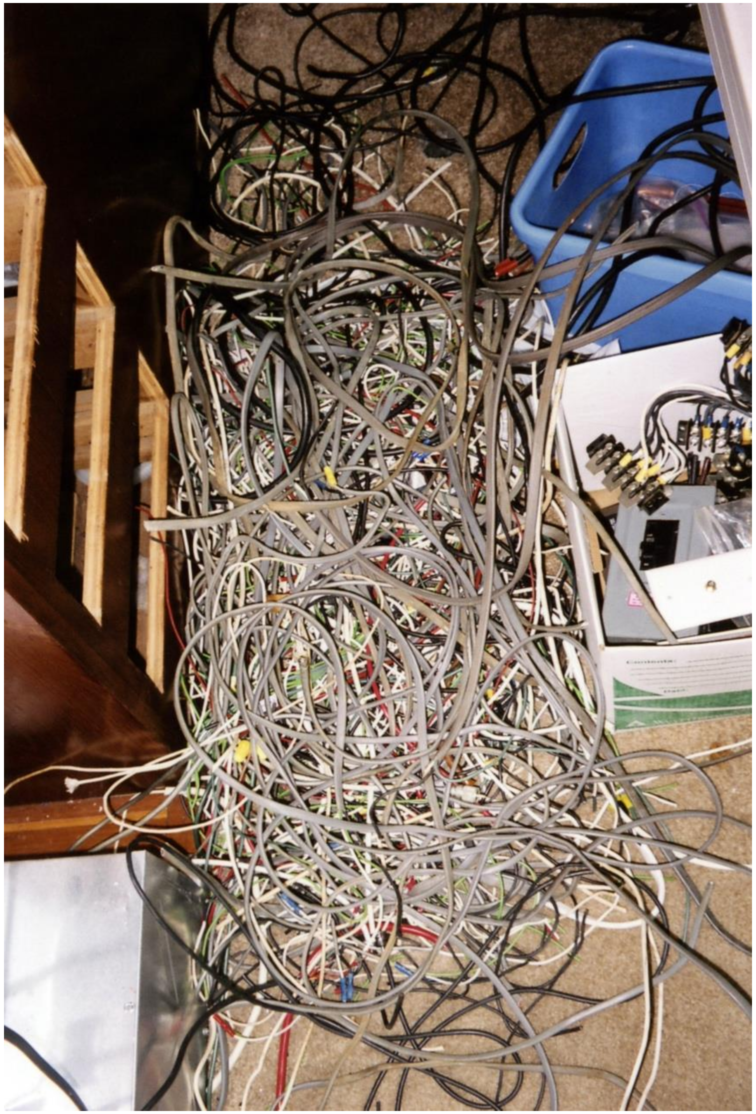
This Afternoon's Syllabus

- Choosing and working with Conductors
- Tools You Want/Tools You Need
- Wire and Cable Termination
- Overcurrent Protection and Circuit Breaker Panels
- Corrosion
- Putting it All Together
- Codes and Regulations
- Safety Practices

Conductors

- AWG (Marine)
- SAE (Automotive)
- ISO (Metric)
- Insulation
- Wire
- UL1426
- Voltage Drop

Grip and Rip



Marine Conductors

- UL 1426 Stranded Copper
- Insulation Type Approved for Service
- Tinned is Good (but NOT required usually)
- Buy from known sources (be wary)

UL 1426

Construction

UL 1426

- 50V or 600V Rating
- Ampacity as stated in Title 33CFR 183.430
- Insulation (Jacket) rated to 105C (75C Wet)
- Flexible Type III Class K Stranding (designed to absorb vibration
- Exceeds USCG and ABYC® Standards
- Accept no Other!

Terminating Wire

- Chosing the Right Tool
- Chosing the Right Terminal
- Matching Tool to Terminal (yes…)
- Testing the Crimp
- Protecting the Crimp

Crimping Tools

- Quality Isn’t Cheap
- Ratcheting is a Necessity
- There is a HUGE $$ Difference between Professional and Good DIY Tools
- Cheap Tools Can’t Make Good Crimps
- Why I use Commercial Airframe Rated Tools

Crimping Wire

- Buy Good Crimpers
  - Rachet
  - Single or Double Crimp (BOTH)
  - Cable Crimpers
  - Cheap Hydraulic Ones (no)
  - Practice (Practice, Practice)

Terminals and L ugs

Quality Terminals:

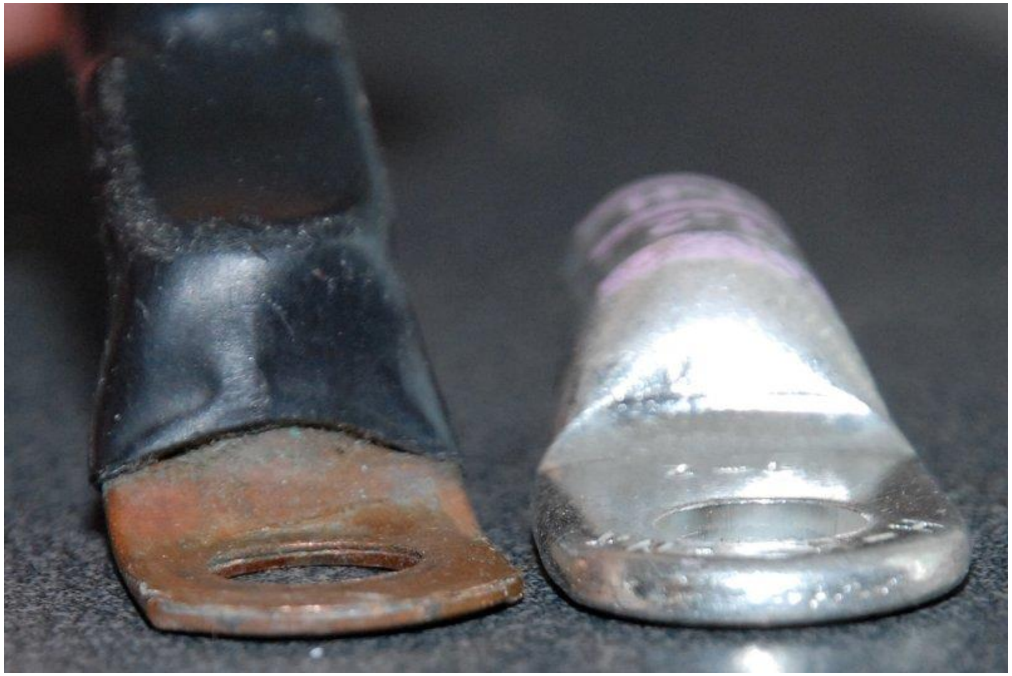
There is no such a thing as marine grade terminals but that is what the better quality terminals have become known as.

Heat shrink terminals, as seen in the top row, are expensive, but in my opinion are almost always well worth it. They are available from manufacturers such as Ancor, AMP, Molex, FTZ, 3M & others.

These terminals stand head and shoulders above the bottom row but keep in mind that they are not sealed connections. As such they are quasi-open to the marine environment. When used in conjunction with UL 1426 tinned marine grade wire these crimp terminals will last a long, long time provided they are not in any direct contact with water, such as in a bilge.*

*Credit Rod Collins marinehowto.com

Battery Lugs

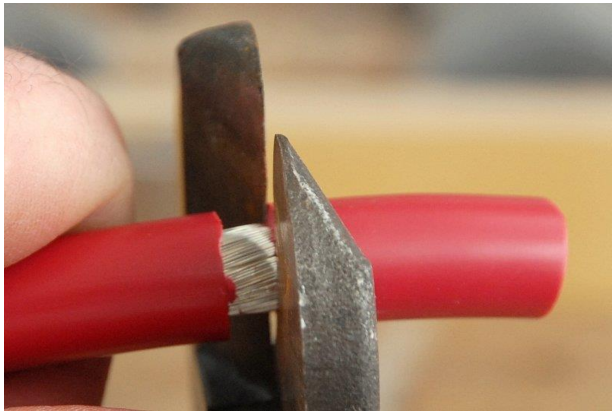


Stripping Wire

- Pick ONE tool and Get Really Good At It!
- Measure and Mark the Wire (1st 100 times!)
- Make a Mistake? START OVER

Battery Cable Stripping

- How I Do It
- How Do You Do it?
- What Tools do You Use?
- There is NO 1 Right Way



Crimping a 10AWG Wire

- Choosing the Terminal
- Match the Wire
- Match the Stud
- Match the Crimper
- Like Wire, Buy from KNOWN Sources
- Many Online Offers are Counterfeit

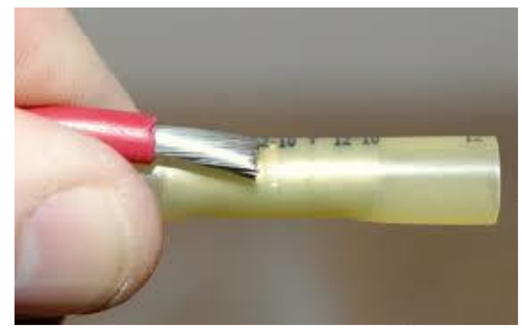
Food 4 Thought

Minimum Crimp Tensile Strength

Wire Gauge	UL486A	DIN 41611/3	NASA-STD-8739-4	Mil-T-7928	ABYC E-11
24	5 lb	8.1 lb	8 lb	10 lb	N/A
22	8 lb	11.1 lb	13 lb	15 lb	N/A
20	13 lb	17.1 lb	21 lb	19 lb	N/A
18	20 lb	25.2 lb	32 lb	38 lb	10 lb
16	30 lb	39.8 lb	41 lb	50 lb	15 lb
14	50 lb	58.0 lb	65 lb	70 lb	30 lb
12	70 lb	92.1 lb	103 lb	110 lb	35 lb
10	80 lb		159 lb	150 lb	40 lb
8	90 lb		288 lb	225 lb	45 lb
6	100 lb			300 lb	50 lb
4	140 lb			400 lb	70 lb
2	180 lb			550 lb	90 lb
1	200 lb			650 lb	100 lb
1/0	250 lb			700 lb	125 lb
2/0	300 lb			750 lb	150 lb
3/0	350 lb			825 lb	175 lb
4/0	450 lb			875 lb	225 lb

LABS

- Design a Conductor
- Mark the Insulation
- Strip
- Crimp
- Lather, Rinse, Repeat
- See One, Do One, Teach One


Over Current Protection

Getting Started

- CRITICAL To Get This Right

Over Current Protection (OCP)

- ABYC E-11
- AIC
- MRBF's
- ANL, T, MEGA, MAXI, ATO, AGC (more)
- Thermal
- Magnetic
- Thermal/Magnetic

Understanding AIC

TABLE 3B - Overcurrent Protection Device Ampere Interrupting Capacity for Systems at or Under 60 V

	TOTAL CONNECTED BATTERY			AMPERE INTERRUPTING CAPACITY (AIC) (amperage available at overcurrent protection device terminals) *See NOTE 2	
	CCA (amperes)	MCA (amperes)	RATED CAPACITY (amp hours)	MAIN AIC (amperes)	BRANCH AIC (amperes)
12 V and 24 V	≤ 650	≤ 810	≤140	1500	750
	651 - 1100	811 - 1375	141 - 255	3000	1500
	1101 - 2200	1376 - 2750	256 - 500	5000	2500
	> 2200	> 2750	> 500	*See NOTE 3	3000
32 V	≤ 1250	≤ 1560		3000	1500
	> 1250	> 1560		5000	2500

NOTES:

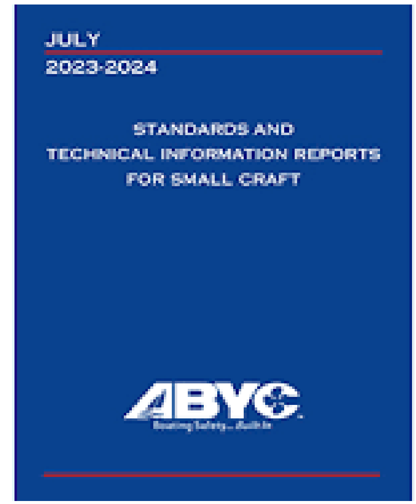
1. *The main circuit breaker(s) is considered to be the first breaker(s) in a circuit connected in series with the battery. All subsequent breakers, including sub-main breakers, connected in series with the main circuit breaker are considered to be "branch circuit breakers."*
2. *This table is relevant to conventional battery technology (lead acid, AGM, Gel) and is not applicable to technologies such as lithium ion and thin-plate pure lead (TPPL), which may require significantly higher AIC ratings.*
3. *See E-11.10.1.2.3 for more information on AIC rating.*
4. *A fuse in series with, and ahead of, a branch circuit breaker may be required by the circuit breaker manufacturer to achieve the interrupting capacity.*

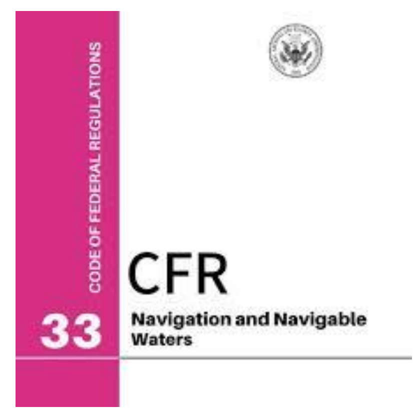
Fuses and Breakers

- Understanding AIC E-11.10.1.2.3.2 (20kA)
- UL 489 and UL1077
- When/What/Where/How 7”/40”/72”
  - Can I ALWAYS use a BREAKER (no)
  - AC and DC Breakers
  - Making the Right Choice
  - Cool Pro Tip

Codes and Regulations Review

- ABYC E-11 and Confusion
- 33 & 46 CFR
- Soldering
- Proper Crimps
- Securing Conductors
- OCP (Musts and Shoulds)
- Pull Tests





See You Tomorrow