InstallingInverter/Charger Systems

Charlie Johnson, PE
JTB Marine Coporation
St. Petersburg, FL
cjohnson@jtbmarine.com
727.323.2500

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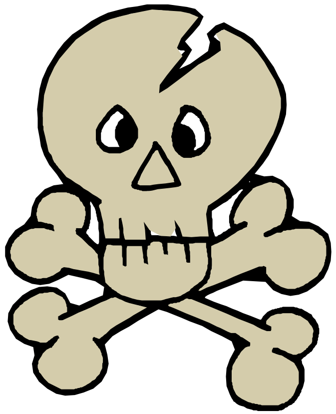
Youare aboutto tryand takea drinkfrom a firehose!!

DireWarnings andDisclaimers

- This presentation will not make you into a competent marine electrician
- JTB Marine Corporation and the presenter assume no responsibility for the use of any of the materials, calculations or methods described in this presentation.



Introduction:
Whoam I?

- Mechanical Engineer
- Retired Naval Engineer: Submarine Maintenance and Repair
- ABYC Certified Marine Electrician
- ABYC Certified Corrosion Technician
- NMEA Marine Electronics Installer
- Amateur Radio Operator: Advanced License
- Live aboard a 53' Gulfstar Trawler; eleven years
- Extensive cruising experience; three years "Down Island mon" in the Eastern Caribbean
- All round nice guy……..

InstallingInverter/Charger Systems: Overview

System Design

EquipmentSelection

System Installation

InstallingInverter/Charger Systems: Overview

The Energy Equation:

Energy In = Energy Out Plus Inefficiencies

InstallingInverter/Charger Systems: Overview

The Energy EquationRestated:

Sources of energy = Users of energyplus inefficiencies

InstallingInverter/Charger Systems: Overview

On today's trawler:

- What are some sourcesof energy?
- What are some users of energy?
- What inefficienciesare encountered?

SystemDesign

- Load calculations
- Battery bank sizing
- Wiring considerations
- Circuit protectiondevices
- Switches

SystemDesign: LoadCalculations

- Be brutally honest...donot hedgeyour numbers!!
- The goal is to arrive at the realistic amount of power that your batterybank is going to have to produceto supply your 12 VDC <u>and</u> your 120 VAC loads.

SystemDesign: LoadCalculations

- First some definitions:
  - Energy is a measure of the ability of a system to do work; the units are watt-hrs
  - Power is rate of energy delivery; the units are watts
    - One thousand watts are equal to one kilowatt
  - The discharge cycle is the amount of time that the house bank will be providing energy to the normal 12 VDC loads and the inverter before being recharged

SystemDesign: LoadCalculations

…and now some simple mathematics:

- Power equals voltagex current

  $P = V \times I$

  (Watts) = (Voltage) x (Current)

SystemDesign: LoadCalculations

Example:

Label plate on the new FRAMUS states:

Voltage: 120 VAC

Frequency: 60 Hz

Current: 1.5 amps

What is the power consumedby the new FRAMUS?

SystemDesign: LoadCalculations

Recallingour formula:

Power equals voltagex current

Or: $P = V \times I$

…andsubstituting forV andI, weget:

$P=120VAC \times 1.5$ amps

=180watts

SystemDesign: LoadCalculations

- The instantaneouspower consumptionof the FRAMUS is 180 watts…
- …howeverwe needthe estimation of the durationthat this appliancew ill be used in order to calculate the energy(watt -hours) requirement

SystemDesign: LoadCalculations

- This partis easy; the energyrequirement is simply the power requirementmultiplied by the durationof use

SystemDesign: LoadCalculations

- Continuingwith our example;the Admiral is going to use the FRAMUS for one hour per dischargecycle
- The energyc onsumedwill be:

  Energy=power x time of usage

  Therefore; the energy requirement is:

  E=180 watts x 1 hour = 180 watt-hours

SystemDesign: LoadCalculations

- Repeat this processfor all of your 120 VAC loads
- Most of the standardtexts have estimates if you cannot find the label plate data
- A simple spreadsheetwould be helpful
- Remember…no cheating!!

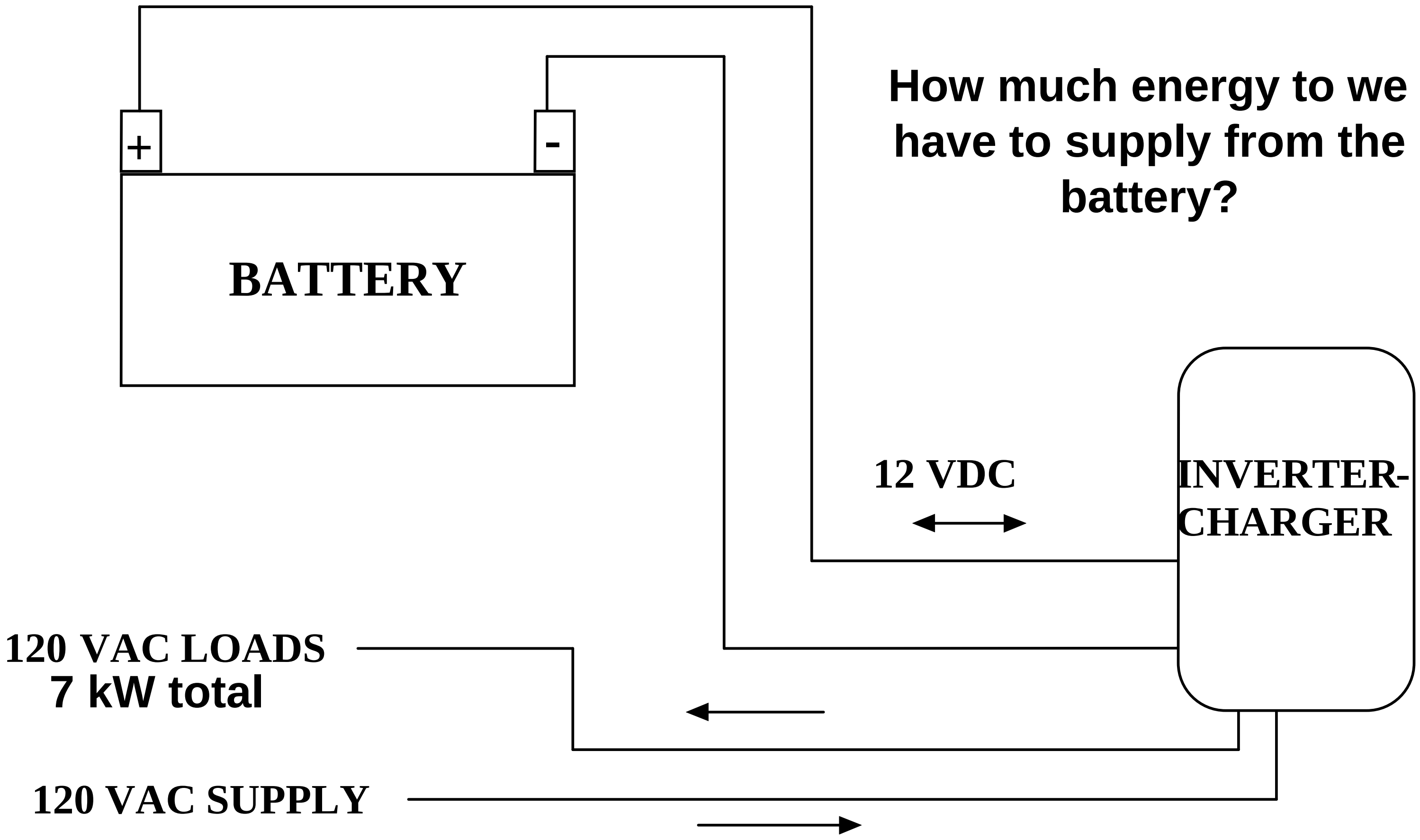
SystemDesign: LoadCalculations

Equipment	Full Load Amps	Watts	Duration of Useage (hours)	Watt-hours	Notes:
FRAMUS	1.5	180	1.0	180	
Refrigerator	2	240	19.0	4,560	1
Stereo System	0.5	60	10.0	600	
Fluorescent Lights	3	360	3.0	1,080	
Mr. Coffee	10	1,200	0.2	240	
Microwave	7	840	0.3	252	
Hair dryer	10	1,200	0.1	120	
			TOTAL:	7,032	

NOTES:

1. Assume an 80% duty cycle

SystemDesign: BatteryBank Sizing



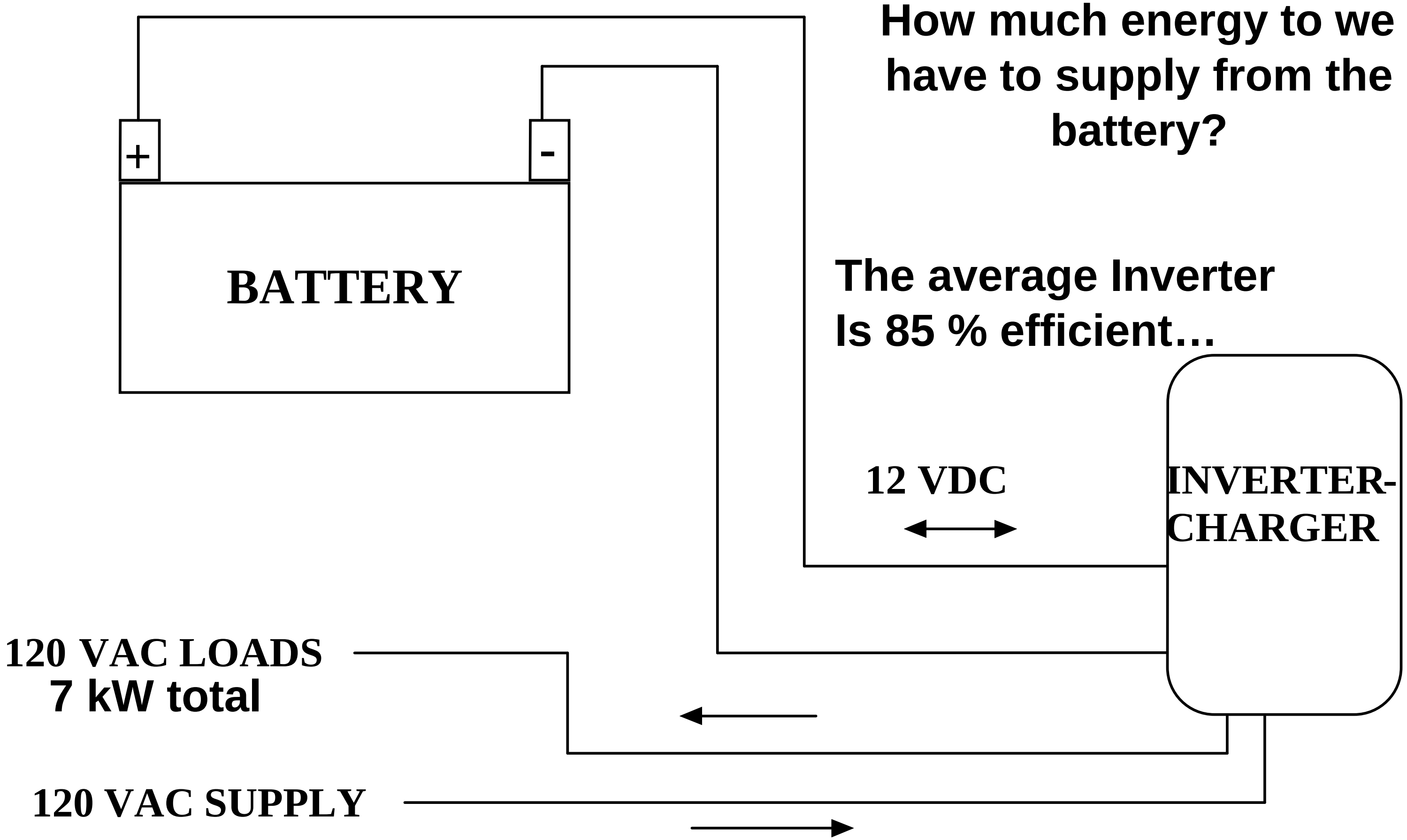
SystemDesign: BatteryBank Sizing

- In a perfect world, energy conversion would take place with 100 % efficiency…therewould be no losses
- In our real world, we have to accountfor losses
- Recall that our 120 VAC loads were calculatedto be 7,032 watts; or about 7 kW

SystemDesign: BatteryBank Sizing

How much energy to we have to supply from the battery?

The average Inverter Is 85 % efficient…



SystemDesign: BatteryBank Sizing

- …a little more mathematics:

  Energy out = Efficiency x Energy in

- Solving for Energy in:

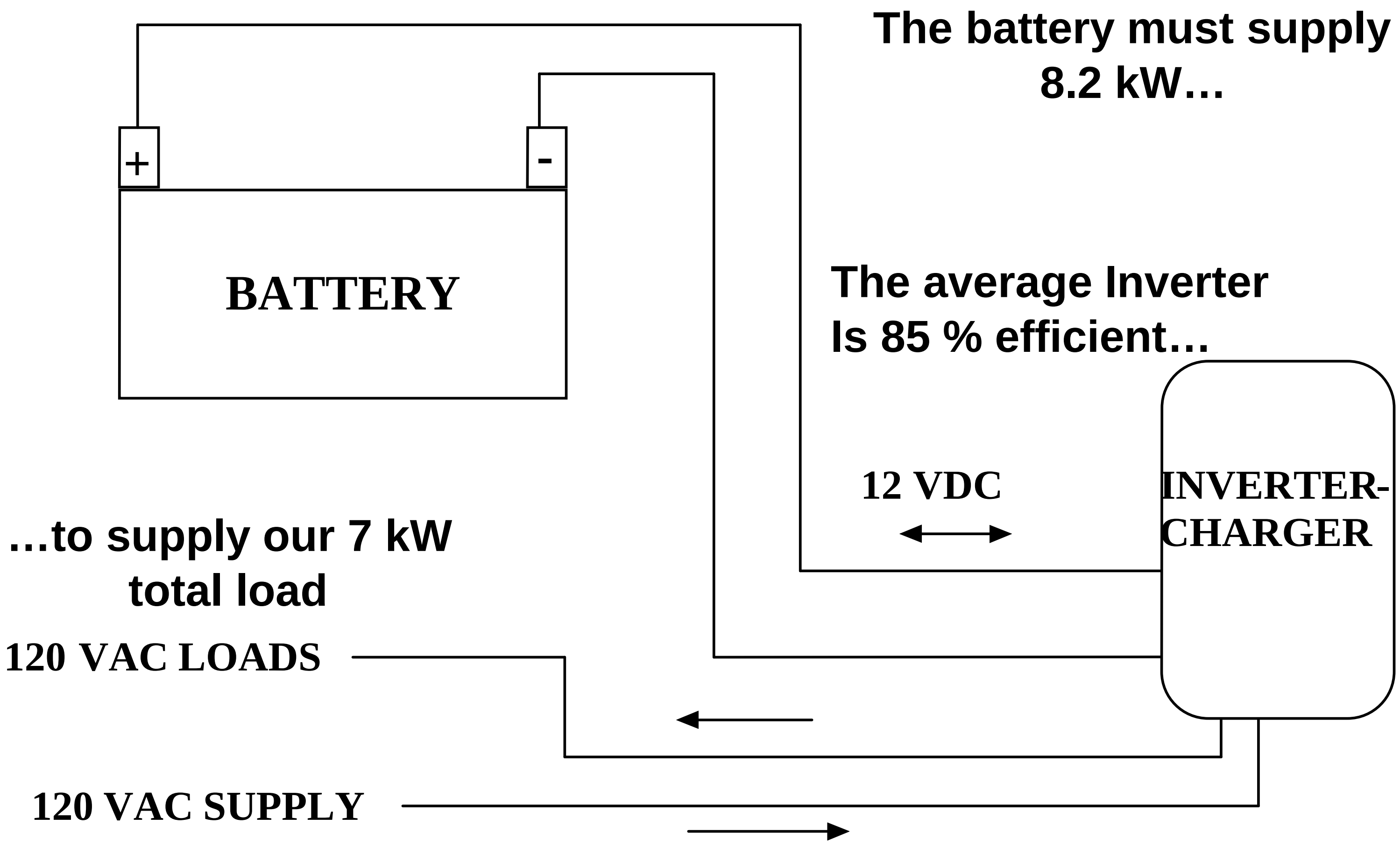
  Energy in = Energy out /Efficiency

- So, for our example:

  Energy in = 7,000 watts/0.85

  = 8,235 watts

SystemDesign: BatteryBank Sizing



SystemDesign: BatteryBank Sizing

- ConvertingWatts → amp-hours
- Recall that: Power = volts x amps
- And: Energy = Power x time
- Therefore:Energy = volts x (amps x time)
- The amp-hour concept is handyto introduce:

  One amp being consumed for one hour is one amp-hour

SystemDesign: BatteryBank Sizing

- Continuingwith our example:

Initial Battery Loads = Energy in/12 VDC

= 8,200 watts/12

= 683 amp-hour

SystemDesign: BatteryBank Sizing

- This is only for the 120 VAC loads supplied by the inverter…
- Must add normalhotel loads for the 12 VDC appliancesaboard
- Again, be brutally honest…a spreadsheet approachcan help
- For ourexample; I am assuming117 amp-hours of 12 VDC load

SystemDesign: BatteryBank Sizing

- The Final Battery Loads=

683 amp-hours+ 117 amp-hours

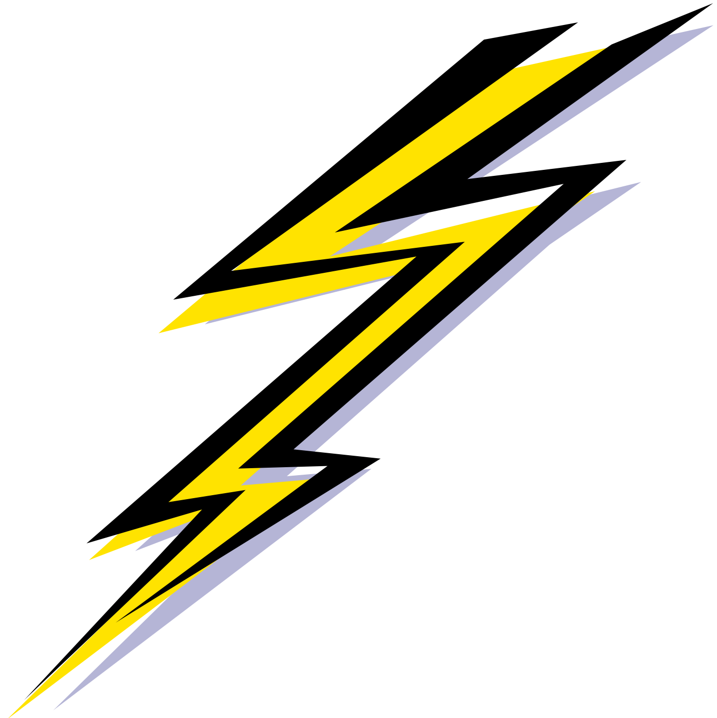
(120 VAC loads) *(12 VDC loads)*

= 800 amp-hours

- This is not a day sailor!!

SystemDesign: BatteryBank Sizing

WOW!!



SystemDesign: BatteryBank Sizing

- Some practicalconsiderations …
  - Deep cycle batteries live longest if you only discharge them to 50% of their total capacity
  - Getting the last 15% of a battery’s capacity back into the battery takes a disproportionate amount of time

SystemDesign: BatteryBank Sizing

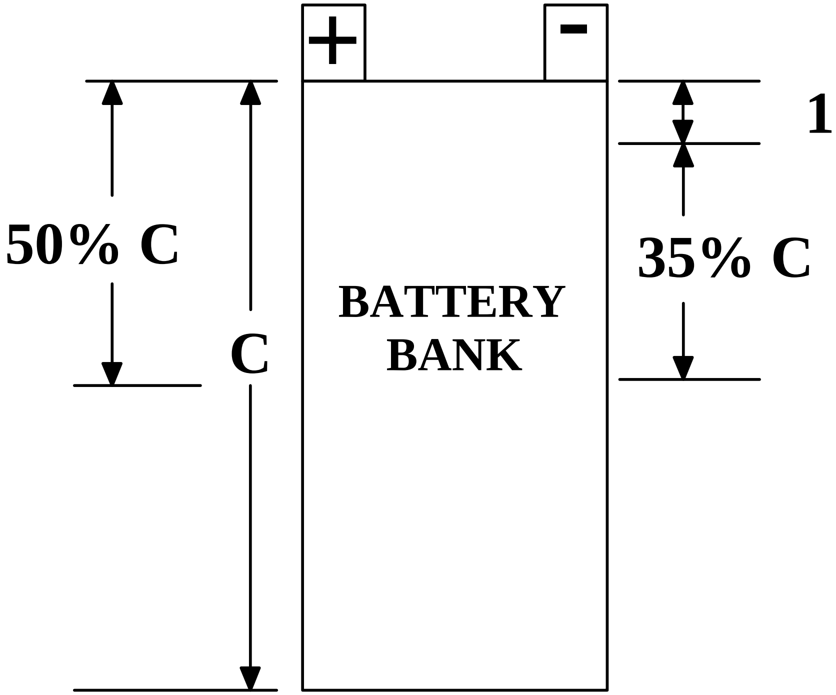
- We arrive at the ideal battery capacity (C) with a little more math:

Battery Loads = (0.5-0.15)C

Solving for C:

C = Battery Loads/ 0.35

SystemDesign: BatteryBank Sizing



The ideal operating range

Example:

C = 1,320 amp-hr
50% C = 660 amp-hr
35% C = 462 amp-hr
15% C = 198 amp-hr

SystemDesign: BatteryBank Sizing

- The IdealBattery Bank for our example would be:

$$C = 800 \text{ amp-hrs}/0.35$$

$$= 2{,}286 \text{ amp-hrs}$$

SystemDesign: BatteryBank Sizing

- Considering only flooded, true deep cycle batteries…

Trojan Model	Capacity (Amp-hr)	Weight (lbs)
T-105	225	62
T-145	260	72
L-16H	420	121

SystemDesign: BatteryBank Sizing

Model	Nr. Of Battery Pairs	Total amp-hr Capacity	Total Battery Bank Weight
T-105	10	2,200	1,240
T-145	9	2,340	1,296
L-16H	6	2,520	1,452

Calculated Ideal Battery Capacity = 2,286 amp-hr

SystemDesign: Wiring Considerations

- Direct CurrentConnections
  - Heavier is better
  - Use the 3% voltage drop tables
  - Use only Tinned Boat Cable
    - BC5W2
      - Insulation rated for 105°C dry
      - Insulation rated for 75° C wet
    - UL 1426
    - Type 3

SystemDesign: Wiring Considerations

- Direct CurrentConnections
  - Do not use SAE Boat Cable
    - On average; approximately 12% less cross-sectional area for the same wire gage
- Use properlysized, tinned, closed end lugs
- Crimp lugs using a box crimping tool
  - Do not us hammer blow type crimpers
- Use adhesive linedheat shrink on lugs

SystemDesign: Wiring Considerations

- If the tables don't allow for the expected current;c alculateusing this formula:

$$CM = \frac{K \times I \times L}{E}$$

SystemDesign: Wiring Considerations

- Where:
  - CM is the req'd. circular mil area of the conductor
  - K is a constant regarding the properties of copper, 10.75
  - I is the current in amps
  - E is the voltage drop; a 3% voltage drop in a 12 VDC system is 0.36
  - L is the round trip conductor length in feet

SystemDesign: Wiring Considerations

- For a sample calculation, assumethe following:
  - The maximum current will be 200 amps
  - The round trip from the B+ bus bar to the inverter/charger and back to the B- bus is 18 feet
  - 3% allowable voltage drop; 0.36

SystemDesign: Wiring Considerations

- Calculating the requiredCM:

$$CM = \frac{K \times I \times L}{E}$$

$$CM = \frac{10.75 \times 200 \text{ amp} \times 18 \text{ ft}}{0.36 \text{ volts}}$$

$$CM = 107,500$$

SystemDesign: Wiring Considerations

AWG	AREA (mm²)	CIRCULAR MILLS ABYC E-11 Table XII
1/0	50	105,600
2/0	62	133,100
3/0	81	167,800
4/0	103	211,600

SystemDesign: Wiring Considerations

- From TableXII, we need2/0 cable
- We need to check to see if 2/0 cable with 105°C insulationcan handlethis kind of load in the engine room.

SystemDesign: Wiring Considerations

ABYC E-11 TABLE IV, ALLOWABLE AMPERAGE		
CONDUCTOR SIZE	105°C INSULATION OUTSIDEOF ENGINE SPACES	105°C INSULATION INSIDEOF ENGINE SPACES
1/0	285	242
2/0	330	280
3/0	385	327
4/0	445	378

SystemDesign: BatteryTerminals

- Use nuts and lock washers to attach lugged conductorsto batteryterminals.
  - Wing nuts forbidden on conductors of AWG 6 and larger (ABYC E10.8.3)

SystemDesign: Wiring Considerations

- AlternatingCurrent Connections
  - Use BC5W2 three conductor AWG #10
  - Run a separate case grounding wire (safety green wire) from the grounding stud provide on the inverter/charger to the 120 VAC safety ground bus

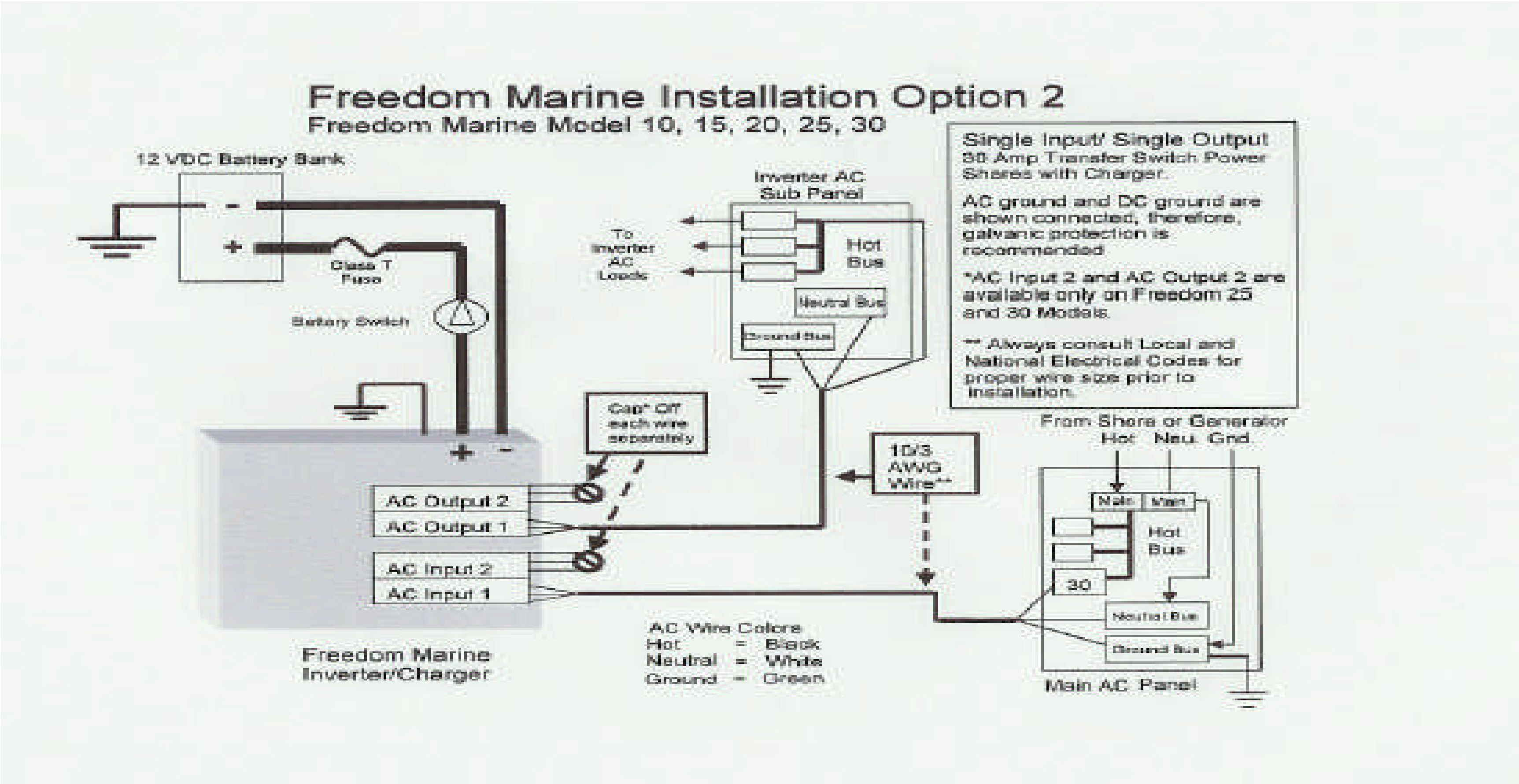
SystemDesign: CircuitProtection Devices

- Install a Class T fuse of the size specified by the manufacturerwithin 7 inches of connectionto the B+ bus
  - If the conductor is sheathed, the fuse can be a maximum of 40 inches from the connection to the B+ bus

SystemDesign: Switches

- Install a remotely accessible inverter/chargerdisconnect switch in the B+ conductor
- Ensure that the output from the inverter is protectedso that the boat's 120 VAC power panelc an only be supplied by ONE SOURCE at a time

SystemDesign: TheBasic Design



EquipmentSelection

- Inverter/Charger
  - Sine wave or modified sine wave
  - Charger requirement
- Charging starting batteries
  - Battery Isolators
  - Battery Combiners
  - Echo Charging
- Battery Monitoring System
  - One bank or two
  - Used to control inverter/charger…or not

DireWarnings andDisclaimers

DireWarnings andDisclaimers

- With the exceptionof the main engine starters,an inverter/chargeris the largest 12 VDC load on the entireboat
- There arer eal design issues that have to be consideredon how to route 120 VAC power to and from the inverter/charger
- Wiring and installationMUST be workmanliketo the extreme…serious problemsc an occur if corners arec ut

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SystemInstallation

- This presentationhas providedyou with:
  - the information that you need to ensure that your inverter/charger is designed properly
  - some of the details to ensure that the installation is properly installed
- If you arethe least bit uncomfortablewith dealingw ith extremely large amountsof DC energy or the120 VAC system….

SystemInstallation

Engage the services of an ABYC Certified Electrician and discuss your planned installationusing this presentationas a guide….

InstallingInverter/Charger Systems

- References
  - ABYC Standards and Technical Information Reports for Small Craft; E10 and E11
  - Boatowner's Mechanical and Electrical Manual; 3rd Ed.; Nigel Calder
  - Powerboater's Guide to Electrical Systems; Ed Sherman
  - Blue Sea Systems; http://www.bluesea.com/
  - Xantrex; http://www.xantrex.com/

AnyQuestions