APLUXOR MARINE ELECTRICAL LIBRARY · PART I. YOUR BOAT AND YOUR METER

Chapter 2. What You Have: Walking Your Boat, the Boat Passport, Someone Else's Boat

Count the sources, draw the diagram, find what is dangerous — on your own boat or on someone else's boat.

In one visit you can learn a boat's electrical system: where its energy comes from, how each source is switched off, what stays live, and which findings need a pro. The same visit works on your own boat and on a charter or a friend's boat, and its result is the Boat Passport: a one-line diagram on one sheet and a set of fields that you keep.

AFTER THIS CHAPTER YOU CAN

- walk your boat from the batteries to the panel in about an hour, with no tools, and list every energy source on it;
- find every circuit that stays live with all battery switches OFF, and the fuse that protects it at the battery;
- recognize a battery switch, a relay (ACR or VSR), a diode isolator, a DC-DC charger, a shunt, a charger, an inverter, the main protection, an ELCI and a galvanic isolator by look, label and wiring;
- fill in the Boat Passport and draw your boat's one-line diagram;
- read the hull identification number and the plates, and tell a US-built boat from a European-built one;
- check out a charter or a friend's boat in 20 minutes, and act when its panel goes dark.

Read first: → 1.7, → 1.8

2.1 The one-hour walk-through
2.2 Recognize each part by sight
2.3 The Boat Passport
2.4 The factory wiring diagram
2.5 US-built or European-built
2.6 Someone Else's Boat in 20 Minutes
2.7 When everything goes dark on an unfamiliar boat
2.8 The minimum tool kit on board
2.9 On board

2.1. The one-hour walk-through, no tools: route, what to open, what to write down

How do you learn, in about an hour and without a meter, where the energy on your boat comes from, how each source is switched off, and what stays live when you believe everything is off? The walk-through answers that question. It needs a flashlight, a notebook, a phone camera and a cloth or plastic measuring tape. A meter adds nothing yet: it gives you a number, and at this stage you need a map.

In a house, all power comes in through one service panel, and one breaker at the top of that panel turns off everything after it. A car has one battery, and every circuit is fed from it. A boat has several sources that work at the same time and do not switch each other off: each battery bank, each shore power inlet, an inverter, a generator, solar panels, a wind generator, and the alternator of a running engine. A battery switch disconnects a bank only from the circuits after the switch. The battery terminals, the cables up to the switch and every circuit wired around the switch stay live in every position (→ 1.7). A device with no source is dead; a source you did not list keeps its circuits live after you believe the boat is off. That is why the walk-through counts sources first and devices second.

The route follows the energy: from the batteries, through their protection and the battery switches, to the DC panel, with a stop on the way at the units wired at the batteries; then from the shore inlet to the AC panel. If you start at the batteries, each stop explains the next one. If

you start at the panel, every breaker sends you back with the question "Where does this come from?" Seven stops make the route (→ Fig. 2.1 · p. 3).

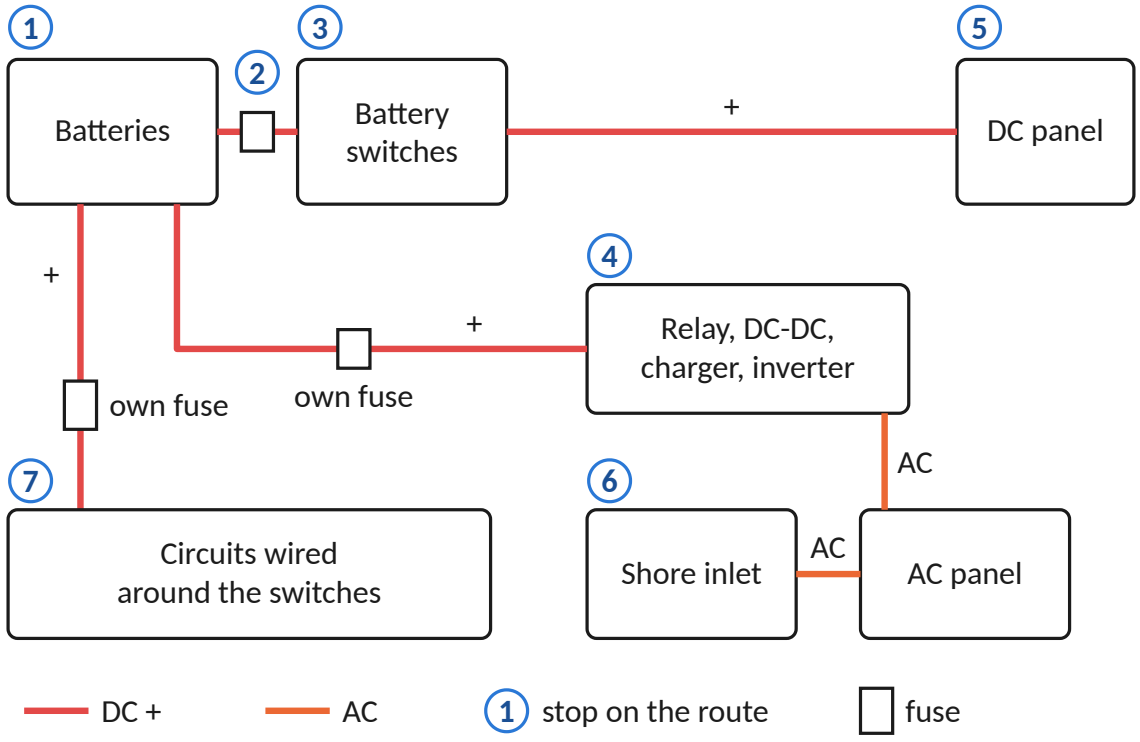


Fig. 2.1. The walk-through route in seven stops, from the batteries to the panels. It is a route map, not the wiring of any one boat: only positive and AC lines are drawn. Every positive line on the map leaves the batteries through its protection, and only the line through the main protection runs through the battery switches to the DC panel. The units of stop 4 and the circuits of stop 7 are wired at the batteries, each with its own fuse there, and stay live with every battery switch OFF.

Before you open any compartment

Three dangers share the compartments of a boat: gasoline vapor, 120 V AC, and the short-circuit current of a battery (→ 1.1). The battery terminals are live in every position of every switch. One thing comes before the first hatch: a record of where everything stands.

> **WALK-AROUND CHECK: BEFORE YOU OPEN COMPARTMENTS**
>
> **Record where everything stands.** Write down or photograph the position of every battery switch, the pump switch, and the charger and inverter switches. Then record what the DC and AC panels

show: which breakers are on, and which lights and meters are lit. This is your return point. At the end of the walk-through every switch goes back to it.

⚠ DANGER TO LIFE · 120 V NEXT TO 12 V

Where the charger, the inverter or the AC panel shares a compartment with the batteries, its terminals carry 120 V from shore power, from the generator, or from the inverter itself. AC at 120 V is dangerous to life (→ 1.1), and the wiring of the two systems can look alike (→ 2.4 · p. 22). On the walk-through you look, read labels and take photographs in such a compartment, and your hands touch no terminal. What is not dangerous: looking and reading there; at the battery itself the danger is the short-circuit current through metal, not 120 V.

Seven stops from the batteries to the panel

WALK-AROUND CHECK: SEVEN STOPS FROM THE BATTERIES TO THE PANEL

SHORT CIRCUIT BLOWN FUSE GASOLINE VAPOR
CARBON MONOXIDE BILGE PUMP

Stop 1 — batteries. Count the batteries and read each label: voltage, capacity in Ah, chemistry, and the date if one is printed (→ 2.2 · p. 8). A battery is one case; a bank is batteries joined by jumpers that work as one. Write each battery on its own line first, then mark which batteries are jumpered together. Until you have traced the jumpers, write “banks not traced” instead of a guess (→ 6.4).

Stop 2 — terminals and main protection. Follow each heavy positive cable from the battery with your eyes: does it go into a fuse, into a switch, or straight into the boat? Every positive cable that leaves a battery is one line in your notes. Write down the protection at the terminal: its type and the rating printed on it (→ 2.2 · p. 8). Then judge its distance from the terminal along the cable; to measure it, lay the cloth or plastic tape along the cable, never a metal one. Of the wires that leave the battery, only the cable that carries the starting current from the battery to the starter, directly

or through the battery switch, is the starter cable and needs no fuse; a wire taken off the starter's battery terminal to feed anything else is not. You identify the starter cable by tracing it to the starter, not by its size (→ 4.2). A jumper between the batteries of one bank is part of the bank (→ 6.4). Any other positive that leaves the battery with no protection is an unprotected positive: write it on the first line of the Boat Passport. Then follow the negative: does the bank's negative cable land on a negative bus or on the engine, does it pass through a shunt, and are there green wires, or green wires with a yellow stripe, nearby (→ 2.4 · p. 22)? The engine block returns current only for equipment mounted on the engine, and it is tied to the negative by its own cable; the hull, the mast, the outboard bracket and the bonding wires never carry a load's return current (→ 1.4).

Stop 3 — battery switches. Find every one: at the helm, near the batteries, in the engine compartment. Write down each position as it is printed (ON and OFF; 1, 2, BOTH; 1+2; ALL; COMBINE), which bank each position connects, and the position the boat runs in when you use it. With two or more switches, give each a number in your notes.

Stop 4 — units wired at the batteries. A relay, a DC-DC charger, a diode isolator, a charger, an inverter: read the maker and the model on each label, and photograph it (→ 2.2 · p. 8). Write down what each one is connected to, as far as you can see it without touching. A relay, a DC-DC charger, a charger and an inverter wired straight to the batteries, not through the switches, keep their DC terminals live with every switch OFF; until you have traced a unit, count it as wired that way (→ 1.7).

Stop 5 — the DC panel. Read the main panel breaker, if there is one, the branch breakers or fuses, their labels and the meters. Write the circuits down as the labels name them, and mark every unlabeled one. ABYC expects every switch and electrical control to be marked with what it does, unless its purpose is obvious and a mistake with it cannot create a hazard; an unlabeled breaker is a question to answer, not a detail. ABYC

Stop 6 — the shore inlet and the AC panel. Read the rating printed on each shore power inlet: volts, amps, and hertz if shown. A boat can have two inlets, and each one is a separate source. At the AC panel write down the shore power breaker, the AC source selector (shore, generator, inverter), the reverse polarity indicator and the branch breakers. Look for a breaker with a TEST button: it can be built into the inlet, be a separate device after the inlet, or be the shore power breaker on the AC panel — boats differ, so trace yours. Look also for a unit that only the green grounding conductor passes through: near the inlet first, then along the grounding conductor toward the AC panel (→ 2.2 · p. 8). If an inlet's rating does not match the pedestal, read → 2.5 · p. 24 before the boat is plugged in again.

Stop 7 — every battery switch OFF: what stays live. This stop finds the circuits wired around the battery switches. Turn the charger OFF, turn the solar charge controller OFF or cover the panels, and turn the large loads OFF, so that no switch opens under a heavy current. Then, with the engine stopped (→ 1.7), press the test button of the carbon monoxide (CO) alarm while the battery switches are still ON, and note whether it sounds; then turn every battery switch OFF — all of them: with one of two switches left on, the other bank keeps feeding the panel, and everything it feeds looks like a circuit around the switch. Now write down everything that still works: a bilge pump, a high-water alarm, the CO alarm, the clock of a stereo or a chartplotter, a charger or charge controller display, the light of a relay. Follow the positive wire of each one to the battery and find its fuse there, by looking, without touching (→ 12.2). Press the CO alarm's test button again. A CO alarm that sounds on this second test is wired around the switch or runs on its own battery; a hard-wired one that sounded on the first test and is dark on the second is wired after the switch; one that did not sound on the first test has no power or has failed — its manual says which. Boats differ, so write down which yours is on the line "CO alarm: what feeds it" of the passport (→ 8.2). A bilge pump that goes

dead with every switch OFF is wired after the switch: a boat left with the switches OFF has no automatic pump. That goes on the first line of the passport (→ 12.2).

Photograph two things at every unit: the label, close enough to read, and the terminals, so that every wire that enters is visible. At the batteries, keep the phone and the flashlight above the level of the terminals. The first photo tells you what the unit is. The second is your "before" picture: after any work you compare against it and see whether a wire moved.

PUT THE BOAT BACK IN SERVICE

- Battery switches back to the positions you recorded, with the engine stopped.
- Charger and charge controller back as they were; the cover off the solar panels; large loads back as recorded.
- The CO alarm: the entry of the CARBON MONOXIDE sign says how you see that it is working again.
- Pump switch where its automatic switch has power and the pump is not running by hand (→ 12.2).

WHY IT WORKS · WHY SO MUCH STAYS LIVE

A battery switch is a contact in the positive cable between a bank and the circuits it feeds. It cannot disconnect what is connected between it and the battery. ABYC allows three groups of circuits to be connected straight to the battery, not through the switch: electronic equipment with memory that must stay powered; safety equipment such as bilge pumps, alarms, CO alarms and bilge blowers; and battery charging equipment. The standard allows this and does not require it, so one builder wires a circuit around the switch where another feeds it after the switch. The walk-through finds out which way your boat is wired instead of assuming it. ABYC

A relay between two banks gives the same result. One relay maker recommends connecting its relay directly to the battery positive terminals, each through its own fuse; its studs are then live whenever the batteries are, whatever the switches show. MFR

2.2. Recognize each part by sight

What is each box, switch and fuse you found on the walk-through, and what does its type change for you? You recognize a part in three ways: by its look, by its label, and by what its wires connect to. The look narrows the choice; the label and the wiring decide it. A table names the parts first (→ Table 2.1 · p. 8); the paragraphs after it explain the parts that look alike.

Table 2.1. The parts of the walk-through by look, label and wiring

Part	Look and label	Wiring that tells you	What it changes for you
Battery switch	A knob or lever; positions printed on its face: ON and OFF; 1, 2, BOTH (or 1+2, or ALL), OFF; ON, COMBINE, OFF	Heavy studs on the back: one per bank and a common output	Which bank each position connects; the working position goes into the passport
Relay (ACR, VSR)	A small case with two heavy studs; the label says ACR, VSR, combiner or the maker's model; a light on some models	One heavy stud to each bank's positive; one thin wire to the negative	While closed, it joins the banks directly; wired at the batteries, its studs are live with every switch OFF
Diode isolator	Heavy studs: one or two inputs and two or three outputs; the label says isolator or diode	The input from the alternator; each output to one bank	Charges several banks from one alternator; the banks never join
DC-DC charger	Terminals marked for input and output; one common negative, or separate input and output negatives on an isolated unit; charge-stage lights or a display	The input from the start bank, the output to the house bank	Between two 12 V banks, its input current is higher than its output current; the input cable and its fuse come from the maker's manual (→ 2.3 · p. 17)

Part	Look and label	Wiring that tells you	What it changes for you
Shunt	A metal block in the bank's negative cable with two heavy studs, and either two small screws or an electronics module with thin wires	The battery negative on one side; every other negative on the other side	The battery monitor never counts current that bypasses the shunt
Bus bar	A bar with several studs or screws; the part itself does not always say positive or negative	On the DC side, red wires mean a positive bus, black or yellow wires a negative bus, green wires a grounding bus; a bar in the AC panel is AC-side work (→ 2.4 · p. 22)	The negative bus and the DC grounding bus are two different bars
Main protection at the battery	MRBF: a flat fuse on the terminal stud in an insulated block; ANL, MEGA, MIDI, Class T: a fuse under nuts on studs in a holder; a breaker: a lever or a reset button	The first part on the positive cable after the terminal	Type, rating, interrupting rating (AIC) and distance from the terminal go into the passport
Charger	AC in, one or more DC outputs	AC from the AC panel; each DC output to a bank	Its outputs carry battery voltage even with shore power off
Inverter	Heavy DC cables in, AC out	DC from a bank; AC to outlets or to the AC panel	It makes 120 V from the batteries
Inverter/charger	Heavy DC cables, an AC input and an AC output	Shore power in; AC out; DC to a bank	Switched off at its front panel, it still has voltage on its terminals

Part	Look and label	Wiring that tells you	What it changes for you
ELCI	A breaker on the boat's shore power, with a TEST button on it or on a module beside it; a RESET button on some models, a handle only on others	In the shore power line: built into the inlet, a separate device after it, or the shore power breaker on the AC panel — boats differ; trace yours	It trips on leakage current; testing and reset → 17.3
Galvanic isolator	A separate unit, near the inlet or along the grounding conductor toward the AC panel; a status panel on some installations	Only the green grounding conductor of shore power passes through it	Part of the AC grounding path (→ 17.4)
Battery	Vent caps: flooded; no caps and AGM or GEL on the label: sealed lead-acid; TPPL or pure lead: thin-plate AGM; LiFePO4: lithium	Jumpers to other batteries make a bank	Chemistry sets the charger profile; for lithium, write down where the BMS is

A box with heavy studs: relay, diode isolator or DC-DC charger

Three different units can sit between a start bank and a house bank, and from across the compartment they look alike: a case with heavy studs. They behave in three different ways, and the difference matters every time you turn a switch or add a battery (→ 8.3).

A relay — an automatic charging relay (ACR) or a voltage-sensitive relay (VSR) — is a heavy contact driven by the voltage it senses. When a bank rises to charging voltage, the relay closes and joins the two banks; when the voltage falls, it opens and separates them. While it is closed, the banks are connected directly, as a battery switch in BOTH connects them. The thresholds belong to the model: one maker's relay joins the banks at 13.6 V after 30 seconds or at 13.0 V after 2 minutes, and separates them at 12.75 V after 30 seconds or at 12.35 V after 10

seconds; another maker's relay joins at 13.7 V and separates at 12.8 V. Read your relay's thresholds on its label or in its data sheet. MFR

A relay also needs a thin wire to the negative to work: one maker lists that wire, through an in-line fuse of 10 to 15 A, among the minimum connections of its relay. A thin wire from the case to the negative bus is therefore part of what you recognize. MFR

A diode isolator has no contact at all. Its diodes pass current one way only — from the alternator to each battery — and never from one battery to the other. It has an input stud for the alternator (two on some models, for two alternators) and two or three output studs, one per bank. The drawback is a voltage loss in the diodes: one maker gives about 0.3 V at low current and about 0.45 V at the rated output of its isolators. MFR

A DC-DC charger is electronics. It takes power from the input bank and delivers a controlled charge to the output bank. Two makers' units have terminals marked for the input from the start battery and for the output to the house battery, and charge-stage lights or a display. Their negatives differ by model. One maker's non-isolated unit has one common negative for the input and the output; another maker's isolated unit has separate input and output negatives, with no connection between them inside the unit. The manual of your model says which one you have. On one maker's unit the last number in the model name is the output current, and the input current is higher (→ 2.3 · p. 17). MFR

Size the input cable and its fuse by the maker's manual, not by the number in the model name: between two 12 V banks, the charger draws more current from the input bank than it delivers to the output bank.

A starter solenoid or a remote-operated battery switch also has two heavy studs and a small control terminal, so the case alone never decides. Read the maker and the model on the label, then the data sheet: thresholds in volts mean a relay; one or two inputs for alternators and two or three outputs mean a diode isolator; an output current and charge stages mean a DC-DC charger. Until you know

which it is, treat every heavy stud of the unit as live with every battery switch OFF.

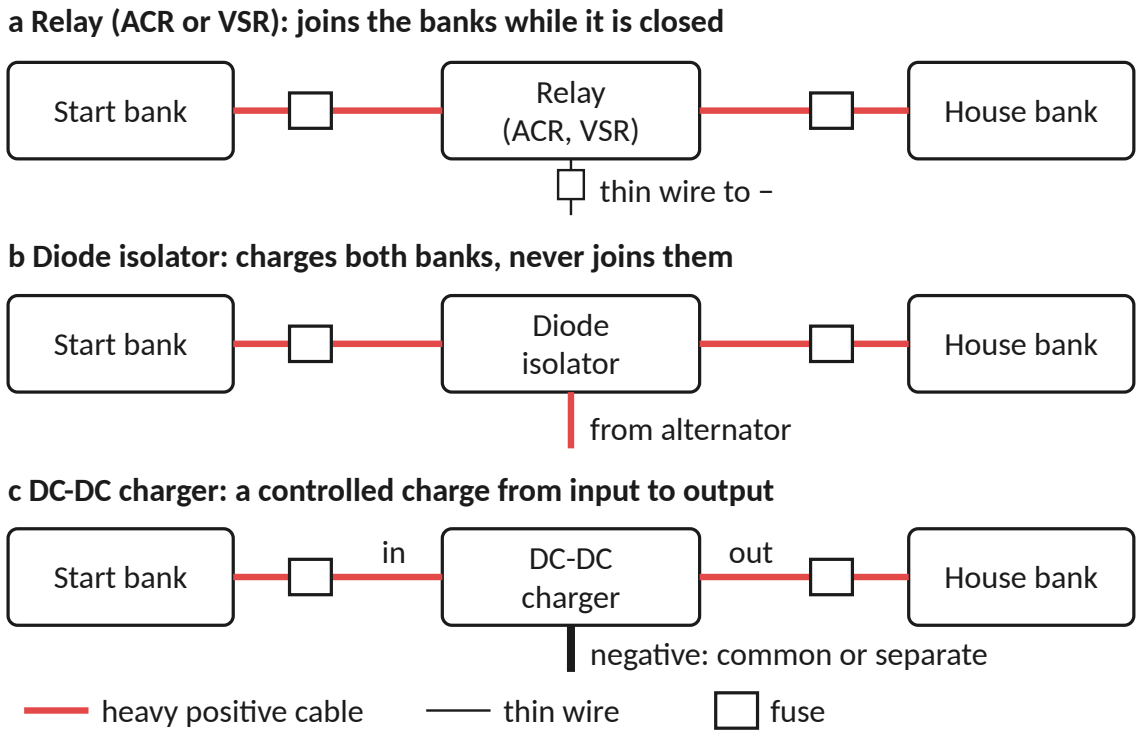


Fig. 2.2. Three units that look alike from across the compartment, drawn on one geometry. The relay joins the two banks directly while it is closed; the diode isolator feeds both banks from one alternator and never joins them; the DC-DC charger takes power from one bank and charges the other. The label and the data sheet tell you which one you have. When the alternator lead is allowed to run without a fuse → 4.2.

Shunts: which wires carry current

A battery monitor counts the current in and out of a bank with a shunt: a calibrated, very small resistance in the bank's negative cable. All the current of the bank flows through it, and the monitor reads the small voltage across it. One maker's 500 A shunt shows 50 mV at 500 A, so every ampere reads as 0.1 mV. MFR

You meet two kinds. A simple shunt has two heavy studs and two small screws; a pair of thin wires runs from the screws to a gauge or a monitor. A shunt with electronics carries a module on the shunt itself. One thin wire with a fuse runs from the module to the battery positive. One or two more thin wires, each with its own fuse near its battery, can run to other banks: one maker's unit has one such input, and another

maker's unit has two. In both kinds, no current of the loads flows in the thin wires. They carry the measurement and power the module; the heavy current flows only through the shunt itself (→ Fig. 2.3 · p. 13).

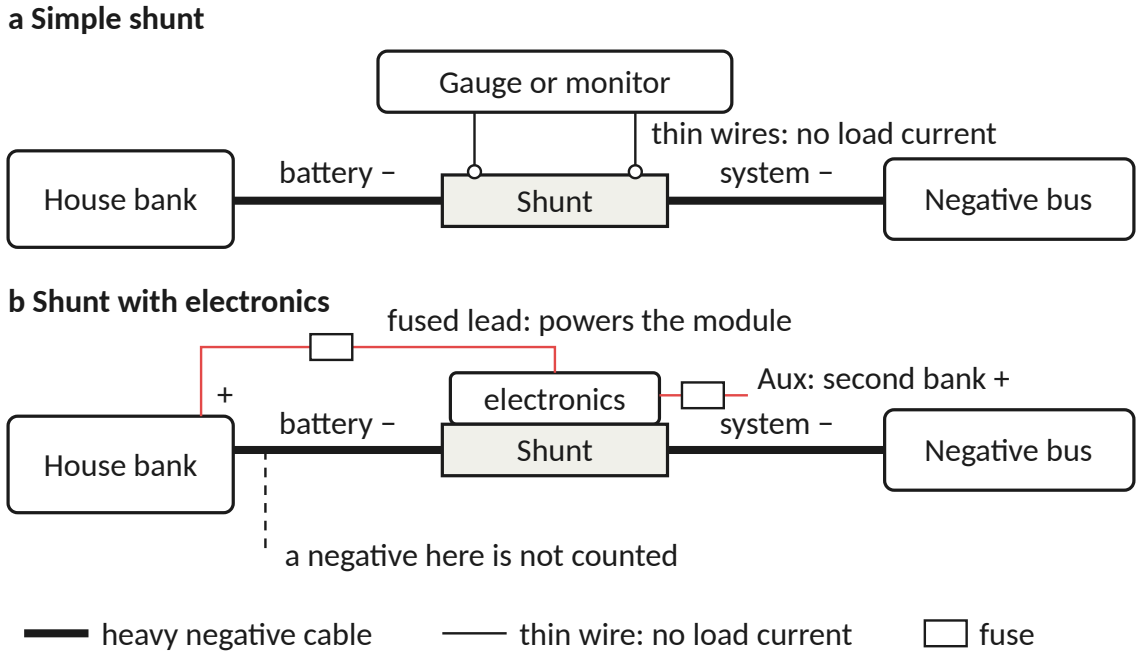


Fig. 2.3. Two kinds of shunt in the bank's negative cable. In both, the heavy current of the bank flows only through the shunt; the thin wires carry the measurement and power the electronics, and each thin lead to a battery positive has its own fuse. A negative connected at the battery terminal, ahead of the shunt, is never counted by the monitor. The number of Aux inputs is on your shunt's label or data sheet.

Both makers of shunts with electronics print the same rule: every negative of every load and every charger lands on the system side of the shunt, and only the shunt lands on the battery negative terminal. A charger negative or a load negative connected straight to the battery terminal bypasses the shunt; the monitor never counts that current, and its percentage drifts away from the truth. At stop 2 of the walk-through (→ 2.1 · p. 2), look at the battery negative terminal. The correct picture is one cable, and it goes to the shunt (→ 3.6).

> **NUMBERS · A SIMPLE SHUNT**
>
> One maker's 500 A shunt shows 50 mV at 500 A. Its resistance is 0.050 V ÷ 500 A = 0.0001 Ω, and at 500 A it turns 500 × 500 × 0.0001 = 25 W into heat. Its maker allows 66% of the rated current continuously — 330 A for this shunt. MFR
>
> A second maker of simple shunts gives two thirds of the rated current as the limit for continuous operation. MFR Your shunt's limit is in its data sheet.

Main protection at the battery

The first part on each positive cable after the battery terminal is its protection. On the walk-through you write down four things about it: the type, the rating, the interrupting rating and the distance from the terminal. The type you read by look. An MRBF is a flat fuse on the battery terminal stud, inside an insulated block; one maker states that the fuse must not be mounted on the battery terminal without that block. ANL, MEGA, MIDI and Class T fuses sit under nuts on studs, in a holder. A breaker has a lever or a reset button.

The fuse body carries its rating in amps and its voltage. The interrupting rating (AIC) — the largest current the fuse can interrupt at its rated voltage and stay intact — is in the maker's data sheet and can be missing from the body. The type alone does not give the number: one maker's ANL fuses list 6,000 A at 80 V; another maker's list 2,700 A, voltage not stated. Write down the AIC from the data sheet of the MFR part that is installed, or "don't know" (→ 4.4).

A fuse is replaced after it blows; a breaker is reset after it trips. What comes first when the main protection of a bank has tripped or blown → 1.8. On a lithium bank the interrupting rating matters most (→ 11.2).

Battery switches: different labels, one action

The positions printed on a battery switch differ by maker, not by what they do. BOTH in one builder's manual, 1+2 on one maker's switch and ALL on another maker's switch mean the same thing: both banks

connected to the common output, and so to each other. A dual-circuit switch marked ON, COMBINE and OFF is a different design: in ON it connects two banks to two separate circuits at the same time, and COMBINE joins the banks. Another maker builds the same function from separate switches and an EMERGENCY PARALLEL switch, which that maker says to use only when both batteries have to be combined for emergency starting. MFR

Some switches carry an alternator field disconnect (AFD): a small extra contact that opens the alternator's field circuit slightly before the main contacts open. It is a line in the model's specification, not something you see on the knob, and it works only with an alternator that has an external regulator. An AFD does not change the battery-switch rule of → 1.7. MFR

Charger, inverter, inverter/charger

Count the AC sides. A unit with AC coming in and DC going out is a charger. A unit with DC coming in and AC going out is an inverter. A unit with an AC input, an AC output and heavy DC cables is an inverter/charger: it charges from shore power, and when shore power stops, one maker's unit starts its inverter by itself. Two makers warn that switching such a unit off at its front panel does not remove the voltage from its terminals. How the inverter is taken off as a source → 1.7. MFR

A charger's outputs are connected to the batteries through their own fuses: one charger maker requires a fuse on each positive conductor from the charger to a bank. With shore power off, the charger stops charging, but its output terminals still carry the voltage of the batteries they are connected to.

Two clues on the shore power line: ELCI and galvanic isolator

An ELCI is a breaker on the boat's shore power that also trips when current leaks out of the AC circuit, for example into the water. Where it sits differs from boat to boat: built into the inlet, a separate device after the inlet, or the shore power breaker on the AC panel — trace yours.

Makers build it differently: one maker's ELCI has a TEST button and a handle that moves to OFF when it trips, with no RESET button; another maker's has TEST and RESET buttons. The lights on such a device MFR mean what its maker's manual says, and no more. One rule, for every design, tells you how to recognize the device: by its TEST button, on the device or on a module beside it; its label (GFCI, GFPE, ELCI, RCD, RCBO or the maker's own name) only confirms it, and a RESET button is not the sign. Testing it and resetting it after a trip → 17.3.

A galvanic isolator sits in the green grounding conductor of shore power. Two makers' instructions put it in series with that one conductor, as close to the inlet as the installation allows; the hot and neutral conductors do not pass through it. Where it ends up differs from boat to boat: look near the inlet first, then follow the grounding conductor toward the AC panel. It keeps small DC currents from flowing between your boat's underwater metal and the dock through the grounding conductor. A status panel exists only on some installations. Write down that the isolator is there and where; what it does on your boat and how it is checked → 17.4.

Battery chemistry by sight

Vent caps on top, with fill wells under them, mean a flooded battery: one maker's maintenance instructions tell you to open the caps and check the electrolyte level. Without vent caps, the label decides: "AGM" or "GEL" on it means a sealed lead-acid battery of that type. If a battery has no caps and its label says neither word, read its type in the maker's data sheet before you set the charger. The difference matters for the charger: a maker of both types requires a voltage-limited charger for gel and AGM batteries (→ 9.3). "TPPL" or "pure lead" on the label marks a thin-plate AGM; its short-circuit numbers belong to that battery model only: read your battery's own data sheet (→ 4.4). "LiFePO4" marks a lithium battery. For a lithium battery, write down where its battery management system (BMS) is: inside the battery case, as on one maker's battery, or in a separate unit that the battery must be connected to, as another maker requires. The BMS decides when the bank disconnects itself (→ 11.4).

2.3. The Boat Passport: one-line diagram and fields

How do you put what the walk-through found on paper, so that you, a pro or the next person aboard can use it without walking the boat again? The Boat Passport is that record: a one-line diagram of the boat on one sheet, and a set of fields. The blank Boat Passport is a free file at apluxor.com; this section explains what each field holds and how to draw the diagram. The fields follow in the order of the blank (→ Table 2.2 · p. 17).

"Don't know" is a valid answer in every field. An empty field is a task for the next walk-through, not a failure. A guess is worse than "don't know": the next person who reads the passport trusts it.

Field 1, the first line of the passport, holds the safety problems not fixed yet: every positive with no protection (→ 4.2) and everything the walk-through marked "Hire a pro". It comes first because it lists what can burn or sink the boat until it is fixed. A finding leaves the first line only when the work is accepted and written in field 16, "Changes and accepted work" (→ 18.6).

Table 2.2. The fields of the Boat Passport

Field	What you write	Section
1. First line: safety problems not fixed yet	Each positive with no protection; each "Hire a pro" finding; the date you found it; the date it was fixed and checked, and by whom	→ 2.1 · p. 2, → 4.2
2. The boat	Name; type (power or sail), length, model year; hull material (fiberglass, aluminum, wood, steel or other); the HIN, every character as on the hull; the date last checked on board; the number of one-line diagram sheets	→ 1.4, → 2.5 · p. 24
3. How the boat was built	US plates / CE plate / both / don't know	→ 2.5 · p. 24
4. Batteries and banks	For each bank: chemistry as printed, volts, Ah, the batteries in it, the date installed; for lithium, where the BMS is	→ 2.2 · p. 8, → 6.1

Field	What you write	Section
5. Common negative	Where each bank's negative lands (negative bus or engine block); whether a shunt is in it; any other wire on the battery negative terminal, which bypasses the shunt. Green bonding wires go in field 14	→ 2.1 · p. 2, → 2.2 · p. 8
6. Battery switches and the working position of each	Where each switch is; its positions as printed; which bank each position connects; the position the boat runs in	→ 2.1 · p. 2, → 8.1
7. Main protection at each bank	Type, rating, interrupting rating (AIC), distance along the wire from the terminal; a different rating or distance set by a pro, with the rule the pro named	→ 2.2 · p. 8, → 4.2, → 4.3, → 4.4
8. Energy sources	Each bank, each shore inlet, each engine's alternator, the generator, the inverter, solar panels, a wind generator: together, the source map of your boat	→ 1.7, → 2.1 · p. 2
9. Converting devices	Charger, inverter or inverter/charger, relay (ACR or VSR), diode isolator, DC-DC charger: where it is, fed from which source, feeding which bank, its fuse	→ 2.2 · p. 8, → 8.3
10. Circuits wired around the battery switches	Each circuit still live with every battery switch OFF, the battery it is fed from, and its fuse at the battery: rating and where it is, or "?". The line "CO alarm: what feeds it" — wired around the battery switch · wired after the battery switch · its own battery · no CO alarm found — and the line "Where it is:"	→ 2.1 · p. 2, → 8.2, → 12.2
11. Bilge pumps and the high-water alarm	For each pump: where it is; the switch type (a panel switch marked AUTO · OFF · MAN, or a separate manual switch with its own automatic switch; a MAN position that springs back or not); the automatic switch (a float switch, an electronic water sensor, or one built into the pump); what feeds the switch — wired around the battery switch · wired after the battery switch; the line "Starts by itself with every battery switch OFF?"; its fuse. High-water alarm: yes or no, and what feeds it — wired around the battery switch · wired after the battery switch	→ 12.2, → 12.3, → 12.5

Field	What you write	Section
12. Models and settings of key equipment	Maker and model as printed: charger, inverter, relay or DC-DC charger, solar charge controller, battery monitor, BMS, CO alarm; for the battery monitor, also its settings as set in its menu	→ 2.2 · p. 8, → 7.6
13. Shore power	Inlets, and the rating printed on each (volts, amps, hertz); leakage protection (ELCI or another device); galvanic isolator; reverse polarity indicator	→ 2.2 · p. 8, → 17.1
14. Bonding wires (green, or green with a yellow stripe)	Whether they are there, and where they meet	→ 2.4 · p. 22
15. Unknown connections and what to find out first	In words, as you saw it: “a heavy red cable into the bulkhead behind the house bank, not traced”; each question for a pro or the maker, with the answer, its date and who gave it	→ 2.1 · p. 2, → 2.3 · p. 17
16. Changes and accepted work	Date, what was done and where, who did it, what was measured	→ 18.6

If one of your banks is lithium, two questions come first, and they go into field 15 with their answers. Do the charger and the alternator that came with the boat suit a lithium bank (→ 11.3)? And what loses power when the BMS disconnects the bank? A bilge pump or a CO alarm fed from that bank goes dead with it (→ 11.4).

> **WORKED EXAMPLE: THE INPUT SIDE OF A DC-DC CHARGER**
>
> Suppose your DC-DC charger delivers 30 A into the house bank at 14.2 V with an efficiency of 87%, the figure one maker gives for its unit, and the start bank feeds it at 12.5 V. Power decides the input current: what comes out, plus what the charger loses inside, must come in. Output: 30 × 14.2 = 426 W. Input: 426 ÷ 0.87 = 490 W. Input current: 490 ÷ 12.5 = 39 A. With equal input and output voltages it would be 30 ÷ 0.87 = 34 A. So the input cable and its fuse carry more than the 30 A of the model name, and the number that sizes them comes from the maker’s manual, not from the name.

The makers' fuse numbers are larger than the model name suggests: one maker gives a 60 A fuse on both the input and the output of its 30 A, 12 V unit; another maker's 60 A unit calls for 80 A on both sides. In the passport, field 9 records where the charger is fed from, which bank it feeds and its fuses, field 12 records its model, and the fuse ratings also go on the diagram. MFR

The one-line diagram

A one-line diagram shows each positive connection as one line; the negative is written in field 5, not drawn. The sources stand on the left, and the lines run right toward the loads. Draw it by these rules (→ Fig. 2.4 · p. 21):

- A small rectangle is protection; write its rating inside or next to it. A rating you could not read is "?".
- A line that leaves a terminal with no rectangle is a positive with no protection; unless you traced it to the starter (→ 4.2), it also goes on the first line of the passport.
- Draw a line only where you traced the connection. Where you lost the wire, stop the line, write "?", and describe what you saw in field 15.
- Everything that stays live with every battery switch OFF goes below a dashed line; each circuit leaves the battery with its own protection (→ 12.1).
- A star (★) marks equipment added after the boat was built; write next to it what it is.
- Draw DC and AC in two colors if you can, and always write "AC" on an AC line: a label survives a black-and-white copy, and a color does not.
- Write the boat's name, the date and the sheet number at the top of each sheet.

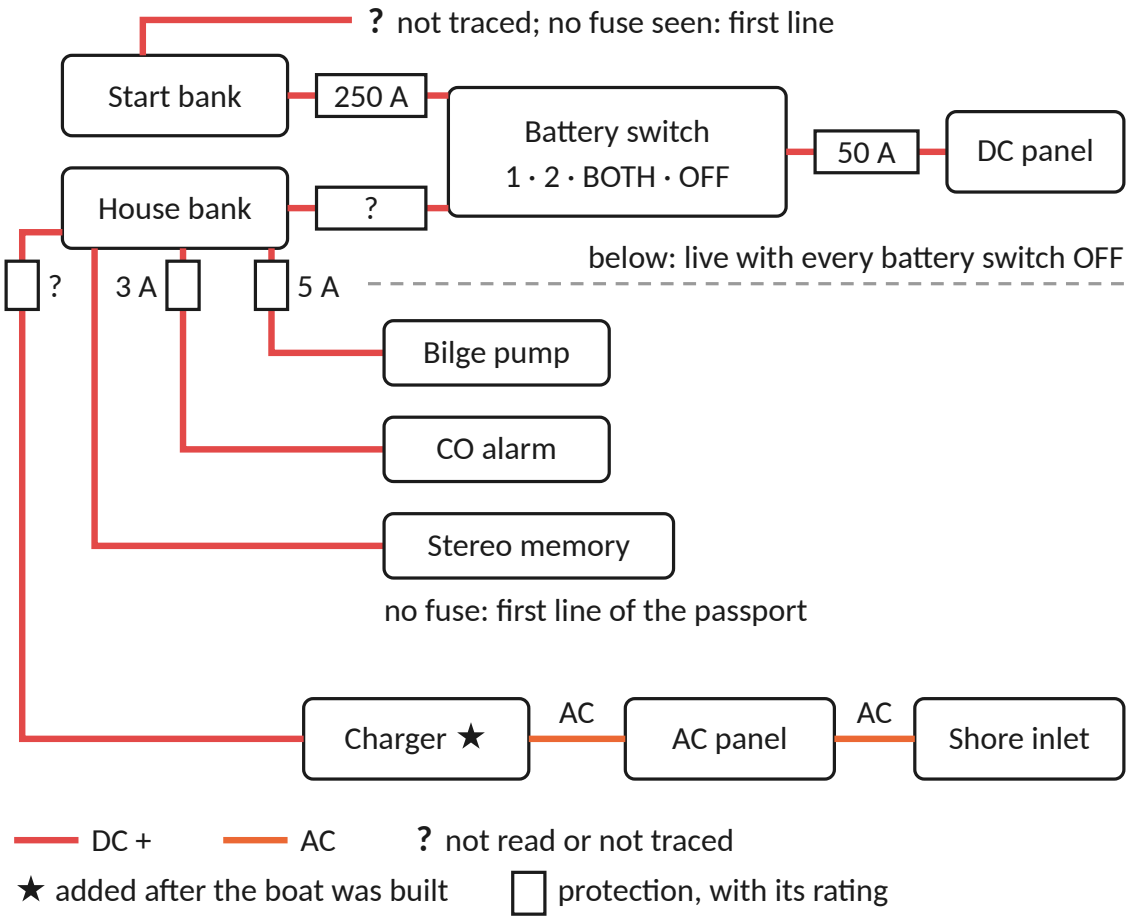


Fig. 2.4. The one-line diagram of a teaching boat, drawn by the Boat Passport rules: protection with its rating, "?" for what was not read or not traced, a separate lane for what stays live with every battery switch OFF, and ★ for equipment added after the boat was built. The ratings are an example, not a recommendation.

A pro who reads your passport before coming aboard brings the right parts and starts from recorded facts. After the work, the pro's measurements go into field 16. That field is what shows the next pro, a surveyor or an insurer what was changed, when, and what the measurements were afterward. Every accepted job updates the passport the same day (→ 18.6).

2.4. The factory wiring diagram: how to read it and where it doesn't match your boat

What does the builder's wiring diagram tell you about your boat, and where does it stop being true? If the builder supplied one, the diagram is in the owner's manual or in its electrical supplement. It shows the model as the builder designed it: the components, the wires between them with their colors and sizes, and the fuses and breakers with their ratings. On a European-built boat the owner's manual includes diagrams that identify the circuits, the location of each device and each conductor (→ 2.5 · p. 24). ISO

Read the legend first, if the diagram has one: it explains the builder's own symbols and abbreviations, and without its legend you can read a relay as a switch and a breaker as a fuse. Then find the three things the walk-through needs: where each bank's positive goes first, what is wired around the battery switch, and where the panel is fed from.

A diagram describes the model on the day it was drawn. Three things change a boat after its diagram is drawn: the dealer's installation, the options, and the work of every previous owner. The owner's manual of one production boat, the Bayliner 2452 Classic Cruiser, says it plainly: "Since the batteries on your boat were dealer-installed, the battery switch positions listed below may vary." The same manual names the circuits wired directly to the battery, which the battery switch does not affect: the CO alarm, which the manual calls the CO monitor, the automatic bilge pumps and the stereo memory. For that model, the manual tells you what to look for. On any one boat of that model the wiring can have been changed since then, and only the walk-through shows what is there now. Every circuit added after the boat was built is missing from the diagram, and its wire can be any color.

Wire colors

ABYC gives a color code for DC wiring (→ Table 2.3 · p. 23). A builder who followed it made the colors meaningful. A builder who did not, and

every previous owner who added a circuit with whatever wire was aboard, made them mean nothing in particular.

Table 2.3. DC wire colors in ABYC E-11, July 2018 edition, Tables 13 and 14 ABYC

Color (abbreviation)	Use
Red	DC positive
Black, or yellow	DC negative
Green, or green with yellow stripe(s)	DC grounding (bonding)
Yellow with red stripe (YR)	Starting circuit: starting switch to solenoid
Brown with yellow stripe (BY), or yellow	Bilge blowers: fuse or switch to blower. Table note: where yellow is used for the DC negative, the table calls for brown with a yellow stripe on the blower wire
Dark gray (Gy)	Navigation lights, tachometer
Brown (Br)	The table's own words: "Generator Armature, Alternator Charge Light, Pumps"
Orange (O)	Accessory feed
Purple (Pu)	Ignition, instrument feed
Dark blue (Dk Bl)	Cabin and instrument lights
Light blue (Lt Bl)	Oil pressure
Tan (Tn)	Water temperature
Pink (Pk)	Fuel gauge
Green with a stripe (G/x), except green/yellow	Tilt down, trim in, or both
Blue with a stripe (Bl/x)	Tilt up, trim out, or both

The color is a hint; the proof is tracing the wire to both ends. In a circuit added after the boat was built, the color proves nothing. A green bonding wire carries no current when the system works correctly. On a boat whose DC negatives are black, a yellow wire can be the bilge blower positive. On a boat wired to the ABYC code, a green wire with a stripe of any color except yellow is trim or tilt power, not bonding. A

black wire can be the hot conductor of 120 V AC wiring. On a 120/240 V boat a red wire can be the second hot. PRACTICE

> ⚠ DANGER TO LIFE · A BLACK WIRE CAN BE 120 V
>
> On the DC side, black is a negative color. On the AC side, the text of the ABYC standard names black as the ungrounded — hot — conductor of 120 V shore power wiring, and white as the grounded one. A black wire behind a panel can be a DC negative at 0 V or an AC hot at 120 V, and its color does not tell you which. On a 120/240 V boat a red wire can be the second hot. Red is also the color of a DC positive. ABYC
>
>  SHORT CIRCUIT  AC — PRO Trace such a wire to both ends behind the panel before you decide what it is; a reading on it starts with the procedure “Proving the AC side off at the AC panel” (→ 3.7). What is not dangerous: a black wire that you have traced to the DC negative bus.

A European-built boat follows other color rules, on both the DC and the AC side (→ 2.5 · p. 24).

Where builders of each boat type and model put the banks, the switches and the chargers is the topic of → module “Boat Types”.

2.5. US-built or European-built: how to tell and what it changes

Who built your boat, when, and to which rules — and what does the answer change for its wiring? The hull number and the plates answer the first two questions. They are clues to the third, not proof: they tell you how the model was designed, and the walk-through tells you what the boat carries today.

The hull identification number (HIN)

A boat built or imported for sale in the United States on or after August 1, 1984 carries a hull identification number (HIN) of 12 characters, with

no slashes, hyphens or spaces. Characters 1 to 3 are the maker's code; characters 4 to 8 are a serial number; character 9 is a letter for the month, A for January through L for December; character 10 is the last digit of the year the boat was built, or certified; characters 11 and 12 are the model year. The Coast Guard's online "Manufacturers Identification" search finds the maker from the first three characters. CFR

"US-" in front of the number is the country code of the United States, not part of the HIN. The regulation requires two identical numbers on every hull. The main one is on the starboard outboard side of the transom, within 2 in of the top of the transom, the gunwale or the hull/deck joint, whichever is lowest. A boat without a transom carries it on the starboard side of the hull, aft, within 1 ft of the stern and within 2 in of the top of the hull side, the gunwale or the hull/deck joint, whichever is lowest. A catamaran or a pontoon boat with replaceable hulls carries it on the aft crossbeam, within 1 ft of the starboard hull attachment. The duplicate is hidden inside the boat or under a fitting, and the characters are at least 1/4 in high. CFR

The HIN is the one place on the boat that must carry the year. The builder's certification label can read only "This Boat Complies With U.S. Coast Guard Safety Standards In Effect On The Date of Certification."

From November 1, 1972 to July 31, 1984, two earlier formats were in use, and their last four characters read differently: decode them with the Coast Guard's HIN guidelines. A boat built before November 1, 1972 was not required to carry a HIN and can have none at all (U.S. Coast Guard, Hull Identification Number (HIN) Validation & Verification Guidelines). CFR

> **WORKED EXAMPLE: THE YEAR FROM THE HIN**
>
> Suppose the last four characters of a HIN read H203. H is the eighth letter: the hull was built in August. 2 is the last digit of the year it was built. 03 is the model year, 2003, and it places the year built at 2002: a boat built in August 2002 as a 2003 model. One digit alone cannot give the decade; the model year and the boat itself give it.

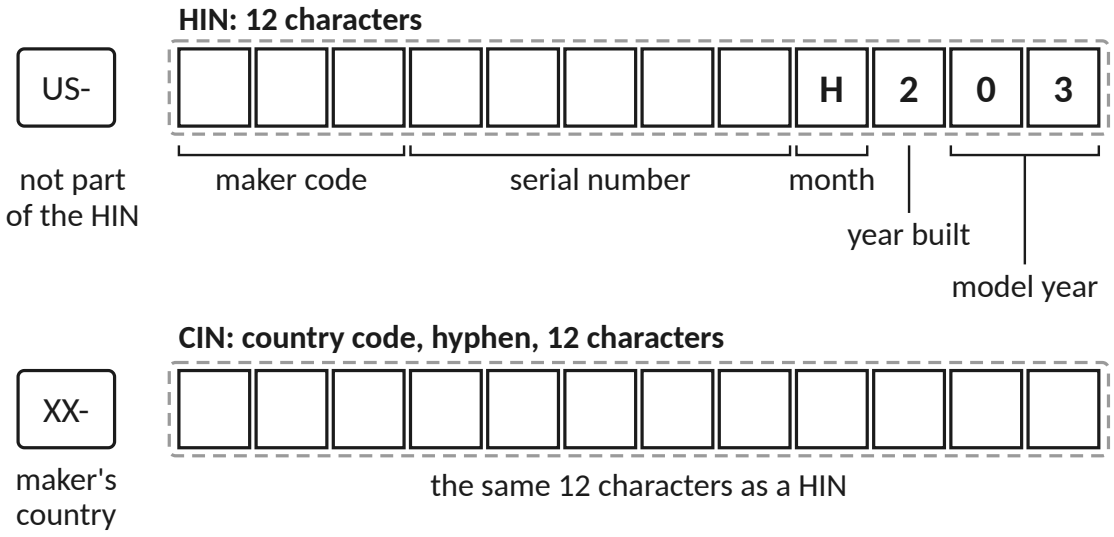


Fig. 2.5. The HIN and the CIN on one grid. Suppose the last four characters read H203: built in August 2002, model year 2003. "US-" in front of a HIN is not part of it. A CIN starts with the maker's country and a hyphen, and the 12 characters after it follow the same order, so the hyphen and the count do not tell a US-built boat from a European-built one.

Plates: what they say and what they don't

A capacity plate gives the maximum number of persons, the maximum weight and, on an outboard boat, the maximum horsepower. The regulation requires it only on monohull boats less than 20 ft long, except sailboats, canoes, kayaks and inflatable boats. On a longer boat, a catamaran or a pontoon boat a capacity plate can be there or not, and its absence tells you nothing. A horsepower line appears only on outboard boats; on an inboard or a sterndrive boat its absence is what you expect. CFR

A plate near the helm can also carry the logo of NMMA certification. That program checks that the model is built to the standards of the American Boat & Yacht Council (ABYC). The logo tells you how the model was designed and built, not how your boat is wired after years of changes.

A European-built boat

A boat built for the European market carries a builder's plate with the CE marking: the builder's name and contact address, the CE mark, a design category, the maximum recommended load and the

recommended number of persons (EU Directive 2013/53/EU, Annex I). The design category — A, B, C or D — describes the wind and waves the boat was designed for. It says nothing about the electrical system. The standard for the plate asks that it be easy to see, names the cockpit or the area near the helm as the preferred place for it, and has it mounted separately from the identification number. ISO

The identification number of such a boat, a craft identification number (CIN), is a two-letter country code, a hyphen and 12 characters in the order of a HIN: the maker's code, a serial number, the month, the year, the model year. The country code names "the country in which the manufacturer is established and not necessarily where the craft is manufactured". So the hyphen and the number of characters do not tell a US-built boat from a European-built one: a US builder's boat for the European market carries "US-" in front of its number, and a CE plate as well (→ Fig. 2.5 · p. 26). ISO

The wiring gives more clues (→ Table 2.4 · p. 27). A wire marked in mm² is a European size — for example, a cable marked 6 mm² (between 10 AWG and 8 AWG) — and its replacement is sized from that marking and is never smaller (→ 5.2, → App. B). European rules allow black or yellow insulation for the DC negative, and require yellow on a boat whose AC system is built to the European AC standard, which allows black for live conductors. In European AC wiring the live conductor is brown, black or gray, the neutral is blue, and the protective conductor is green-and-yellow (CENELEC HD 308 S2). ISO

Table 2.4. Clues to how a boat was built

Clue	US-built boat	European-built boat
Identification number	HIN: 12 characters; "US-" can stand in front of it	CIN: country code, hyphen, 12 characters
Plate	Capacity plate (monohull under 20 ft) or certification label; NMMA logo on certified models	Builder's plate with the CE mark and a design category A to D
Wire size	AWG	mm², as printed

Clue	US-built boat	European-built boat
DC negative	Black or yellow	Black or yellow; yellow on a boat with AC wiring to the European AC standard
AC conductors	Black hot, white neutral (the ABYC text); on 120/240 V a second hot, red; green grounding	Brown, black or gray live; blue neutral; green-and-yellow protective
Shore inlet rating	Printed 125 V or 125/250 V (a 120 V or 120/240 V system), 60 Hz	Can be 230 V / 50 Hz (→ 17.1)

Each of these is a clue to what the builder designed, not proof of what the wiring is after refits. A European-built boat rewired in the US can carry AWG wire, and a US-built boat can carry a European charger. The protection at the battery of a European-built boat was placed by European rules. Compare it with the protection rule for a US boat (→ 4.2) before you decide what an upgrade to ABYC changes (→ 18.5).

Outside North America, a marina pedestal can supply 230 V / 50 Hz. The steps are the same. Read the rating on the pedestal and on your boat's inlet: if the voltage or the frequency does not match, do not plug in — an adapter changes the plug, not the voltage (→ module "230 V Boats").

The same rule applies at a US dock. An inlet labeled 230 V / 50 Hz is not plugged into a US pedestal of 120 V or 120/240 V, 60 Hz: making such a boat work here is a job for a pro, and your part stops at reading the label (→ 17.1).

2.6. Someone Else's Boat in 20 Minutes

You step aboard a charter boat, a friend's boat or a boat you are thinking of buying. In 20 minutes, how do you find out where the energy is switched off, whether the equipment your safety depends on works, what you must not touch, and what to tell the base or the owner? On someone else's boat you have no diagram, no history and no right to change anything. You have 20 minutes before you leave the dock, and a person ashore who can answer questions. So the goal is

narrower than on your own boat: not the whole system, but those four answers.

On someone else's boat there are three levels, not four: switches and buttons — yes; tools — no; the gray zone — only with the permission of the charter base or the owner, by phone. The gray zone is anything you are not sure is a switch or a button.

The reason is not politeness. Whatever you change with a tool stays in the boat, and the next crew inherits it without knowing. And you cannot check your own result: you know neither the boat's earlier state nor its wiring, so you cannot tell a fault you caused from a feature of this boat. A switch or a button shows its whole result immediately — the pump runs, the light comes on — and leaves nothing behind that was not there. A fuse replaced, a terminal tightened or a wire moved stays after you leave; on this boat such work is the decision of the base or the owner.

A charter base briefs you on the boat, and how much of the electrical system the briefing covers differs from base to base. One base's written briefing lists the electrical panel, the battery monitor and the charger and inverter switches, and says that its boats are set up so that you do not need to handle the battery switches. The 20-minute check fills in what the briefing leaves out, and it follows what the base told you: where the base says not to touch the battery switches, you do not touch them. The battery switches are the one exception among the switches: they set how the base wired the boat to run, so on someone else's boat you turn them only with the permission of the base or the owner, except to bring a dark panel back (→ 2.7 · p. 33).

On a boat you are thinking of buying, the same three levels hold, because the boat is the seller's until you buy it. The 20-minute check is not a survey: it gives you questions to ask the surveyor (→ 18.4).

ON SOMEONE ELSE'S BOAT

1. **Find:** the battery switches and their positions, the main panel breaker, the pump switch and its position, the shore inlet and the protective device with a TEST button, near the inlet or on the AC panel.

2. **Check:** by the 20-minute check below — the panel's voltage with shore power unplugged, the bilge pump and the navigation lights; what stays live with every battery switch OFF only with the base's permission.
3. **Don't touch:** wires, terminals, fuses and connections; BOTH, 1+2, ALL or COMBINE, or turning a parallel switch ON, without the base's permission.
4. **What to tell the base or the owner:** what does not work, when you noticed it, what you switched, and the readings you saw.

The form for the check follows (→ Table 2.5 · p. 30). Print it or copy it into your notes before you go: its lines follow the order of the check, and its last line is your report to the base or the owner. The same check and form are a free file, "Someone Else's Boat in 20 Minutes", at apluxor.com.

Table 2.5. Someone Else's Boat in 20 Minutes: the form

What	Where you read it	Your entry
Boat, date, time	—	_____
Battery switches: positions at check-out	At each switch	_____
Pump switch: position at check-out; separate switch or AUTO / OFF / MAN	At the panel	_____
Voltage with shore power off	Panel voltmeter or battery monitor	_____ V
Battery monitor, if installed	The monitor	_____ %
Lowest house-bank voltage the base gives	The base's briefing	_____ V
Circuits live with every battery switch OFF	The base, or your check with the base's permission	_____
Shore inlet rating	The inlet	____ V ____ A ____ Hz
Protective device with a TEST button: where	Near the inlet or on the AC panel	_____

What	Where you read it	Your entry
Bilge pump in MAN: runs; water goes overboard	At the pump switch	yes / no; yes / no
Navigation lights that do not work	Each light	_____
What you switched, and back to where	Your notes	_____
Reported to the base or the owner: when, to whom	—	_____

WALK-AROUND CHECK: SOMEONE ELSE'S BOAT IN 20 MINUTES

GASOLINE VAPOR BILGE PUMP AC — PRO SHOCK IN WATER

First minute — the starting state. Write down the position of every battery switch and of the pump switch, and what the panels show. Without this record you cannot return the boat as you found it, and the next crew will not know what changed.

Minutes 1 to 5 — batteries and switches. Find the battery switches and write down their positions as printed. If the boat smells of gasoline, call the base or the owner; the check waits until the smell is gone. Then look at the batteries and at the protection at their terminals, without touching them.

Minutes 5 to 10 — the panel and what stays live. Take shore power off, in the order of → 17.2: with shore power on, the charger keeps the panel voltage high and hides the state of the bank. Then read the panel voltmeter or the battery monitor, and write the number on the form. If the base gives a lowest voltage for the house bank, write it next to your reading. Ask the base which circuits stay live with the battery switches OFF. Only if the base allows you to turn the battery switches, check it yourself: charger OFF, solar charge controller OFF or panels covered, large loads OFF, then, with the engine stopped (→ 1.7), every battery switch OFF; write down what still works, and put every switch back right away.

Minutes 10 to 15 — shore power. Read the rating on the shore inlet (→ 2.5 · p. 24), find the protective device by its TEST button — in the inlet, after it or on the AC panel (→ 2.2 · p. 8), and find the reverse

polarity indicator. Then plug back in, in the order of → 17.2. If a protective device on the boat trips, it is reset with a button or a handle, so you are allowed to reset it on someone else's boat, as on your own: by the card "Shore power tripped and won't come back on" (→ emergency card). Then tell the base or the owner what tripped and what you did.

Minutes 15 to 20 — the bilge pump and the lights. If there is water in the bilge, run the pump in MAN for a few seconds: it runs, and water goes overboard; then the switch goes back to where you found it. Ask the base when the float switch was last tested. Lifting the float by hand is the gray zone: ask the base or the owner first, and lift it only with their permission (→ 12.1). Turn on the navigation lights one at a time and note any that do not work.

PUT THE BOAT BACK IN SERVICE

- Every switch you turned, back to its recorded position, with the engine stopped.
- Pump switch where its automatic switch has power and the pump is not running by hand.
- Shore power that is off after a trip, or because the reverse polarity indicator lit, stays off: tell the base or the owner.
- Tell the base or the owner that the switches were touched.

Suppose the panel reads 12.3 V with shore power unplugged, the anchor light does not come on, and the pump runs in MAN. A report the base can act on sounds like this: "The panel reads 12.3 V with shore power unplugged. The anchor light does not work; the other navigation lights do. The bilge pump runs in MAN and moves water. With the engine stopped, I turned the battery switches OFF for one minute and put them back to 1 and 2, as I found them." A report like that lets the base send the right person with the right part; "something is wrong with the electrics" does not.

2.7. When everything goes dark on an unfamiliar boat

The panel of a boat you do not know has gone dark. What do you do, in what order, and where do you stop? Start with what can hurt people, before you touch any switch:

- The engine is running and you are under way: get to safe water or anchor first, then stop the engine; until then the battery switches stay as they are (→ 1.7).
- Smoke, a burning smell or a hot case: stop here and go to the card "Smoke, a burning smell, or an overheated wire" (→ emergency card).
- You are at sea and have lost your navigation and your radio: go to the card "The panel went dark — no lights, no electronics" (→ emergency card).

On your own boat, use the card "The panel went dark — no lights, no electronics" and the full sequence (→ 19.6). This section is for a boat you do not know, where you do not take several of the usual steps: you do not know where the fuses are, and you do not replace them (→ 2.6 · p. 28).

WHAT CHANGED BEFORE THE PROBLEM?

- after you installed or changed a device → switch that device off and check it first (step 3)
- after charging → note which source was charging; a lithium bank can disconnect itself (→ 11.4), and the base needs to know it (step 8)
- after rain or washing the boat → look for water on the panel and its connections, without touching them (step 1)
- after the boat sat unused → check for a discharged bank: read the voltmeter or the monitor if it still shows anything (step 6)
- after switching sources (shore power, generator, inverter) → the AC side alone can be dark (step 7)
- nothing you noticed → step 1

PROCEDURE: A DARK PANEL ON SOMEONE ELSE'S BOAT

 GASOLINE VAPOR  BLOWN FUSE  BILGE PUMP  CARBON MONOXIDE
 HOT BATTERY  AC — PRO  SHOCK IN WATER

If the boat smells of gasoline, start with the entry of the GASOLINE VAPOR sign above; the steps below wait until the smell is gone, and you call the base or the owner (→ 1.1).

1. Look at what went dark: the 12 V lights and instruments, only the 120 V outlets and shore equipment, or both. If you cannot tell, name two things that do not work and one that does. Look also for water on the panel and its connections, without touching them.
   You will see: Only the 120 V side is dark: go to step 7 and leave the battery switches alone.

2. With the engine stopped (→ 1.7), a battery switch at OFF goes to the position you recorded at check-out (→ 2.6 · p. 28) — where that is BOTH, 1+2 or ALL, to 1; where it is COMBINE, to ON. If you did not record it, call the base. If you cannot reach the base, use ON, or 1 on a switch marked 1, 2 and BOTH (or 1+2, or ALL). Do not move the switch from one bank to the other before the main protection of the bank in use and the main panel breaker are checked (steps 3 and 4). Do not choose BOTH, 1+2, ALL or COMBINE, or turn a parallel switch or a charging relay's own combine control ON, before steps 3 and 4 have found the main panel breaker and the main protection intact, and then only with the base's permission: these positions and those controls join the banks directly, and on a boat with a lithium bank they join lithium and lead-acid directly, past whatever charges one bank from the other.
   You will see: The panel comes back: the switch was off; tell the base. It stays dark, or the switch was already in its position: go to step 3.

3. Switch off the device that was switched on right before the panel went dark. Then look at the main panel breaker. If it has tripped, reset it as → 4.8 shows; on this boat the battery

switch then goes to the position step 2 gives — 1 where the recorded position is BOTH, 1+2 or ALL, ON where it is COMBINE — and the pro is sent by the base or the owner.
You will see: The panel comes back and stays on: write down what you switched off and tell the base. It trips again: call the base or the owner. No breaker has tripped: go to step 4.

4. Look at the main protection of each bank at the battery, without touching it; on someone else's boat you do not replace fuses. If the main panel breaker has not tripped and every main protection is intact (not tripped, not blown), turn the battery switch to the other bank — 2 from 1, 1 from 2 — with the engine still stopped.
You will see: The panel comes back on the other bank: the first bank is discharged; tell the base. A main protection has tripped or blown: the panel stays dark, and a bilge pump fed after that protection has stopped with it; call the base (→ 1.8).

5. If one circuit is dead and the others work, look at its branch breaker. If it has tripped, reset it as → 4.8 shows. If that circuit feeds a bilge pump and does not come back, the boat has lost that pump: call the base.
You will see: It does not trip again: the circuit works. It trips again: a note on it for the next crew, and the base hears which circuit it is.

6. Check what is still alive. If there is water in the bilge, put the pump switch in MAN for a few seconds and then back; look at the high-water alarm and the CO alarm. If the panel voltmeter or the battery monitor still shows a number, write it down.
You will see: If the pump is wired around the battery switch (the Boat Passport or the base knows): the pump runs in MAN and the alarms are alive — that bank and its negative are alive, and the break is in the path to the panel or in another bank that feeds the panel; the pump is dead as well — the break is in what they share: the bank, its main protection or the common negative. If the pump is wired after the switch, or you do not know how it is wired, a dead pump tells you nothing new. Write down by name what works and what does not.

7. On the shore power side, look at the shore power breaker on the AC panel and at the pedestal breaker. A device on the boat that has tripped is reset by the card "Shore power tripped and won't come back on" (→ emergency card) — on someone

else's boat too, because it is reset with a button or a handle (→ 2.6 · p. 28). A tripped pedestal breaker belongs to the marina: tell the base. A lit reverse polarity indicator: unplug in the order of → 17.2, and tell the base (→ 17.3).

You will see: Shore power comes back and stays on: the 120 V side works. It trips again: tell the base what tripped and what you did.

8. Call the base or the owner: what went dark, what you switched, which breaker stays off, and what still works. On someone else's boat you go no further than these steps (→ 2.6 · p. 28).

You will see: The base knows the state of the boat before a pro or the next crew comes aboard.

PUT THE BOAT BACK IN SERVICE

- Switches you changed on working circuits, back to the recorded positions, with the engine stopped. A battery switch whose recorded position is BOTH, 1+2, ALL or COMBINE stays at the position step 2 gives until steps 3 and 4 have found the main panel breaker and the main protection intact and the base allows the recorded position.
- A breaker you left off, with its note, stays as it is.
- Pump switch where its automatic switch has power and the pump is not running by hand.
- Shore power that is off after step 7 stays off; tell the base or the owner.

> **WHY IT WORKS · WHY A RUNNING PUMP SHOWS WHICH BANK IS ALIVE**
>
> A bilge pump wired around the battery switch draws straight from its bank through its own fuse at the battery. If it runs in MAN while the panel is dark, that bank has voltage and its negative path is complete. The break then lies in the path from a bank to the panel — the switch, the main protection, the main panel breaker, the feeder — or in another bank, if the panel is fed from one. If the pump in MAN is dead as well, something that both paths share has failed: the bank itself, its main protection at the terminal, or the common negative. The reasoning holds only where the pump is wired around the switch. On a boat whose pump is wired after the switch, a dead pump tells you nothing new; the passport, or the base, knows which way the pump is wired.

2.8. The minimum tool kit on board

Which tools do you need for everything this book has you do yourself, and which are not worth buying? The kit is short because it covers only the work on your side of the line between your work and a pro's (→ 1.8). A tool for work beyond that line is not worth buying: that work goes to a pro.

- **A multimeter**, the main tool. It measures voltage, and the voltage drop across a part of a circuit under its real working current. An ohmmeter cannot see hundredths of an ohm, so a bad connection is found by voltage drop (→ 3.4). Four properties decide which meter is good enough (→ 3.2). For the one AC measurement this book has you make — proving 0 V at the AC panel (→ 3.7) — the meter is rated at least CAT III 600 V.
- **A battery-powered proving unit**, if you will prove the AC side off yourself: with the boat's AC side off, it is the practical known live AC source on which you prove the meter before and after the measurement (→ 3.7).
- **A ratcheting crimper** made for the kind of terminal you use — for marine heat-shrink terminals, one made for them — with cavities for their sizes, and a heat gun for the heat shrink (→ 5.6).

- **A headlamp**: on a boat both of your hands are busy.
- **Spare fuses** of every type and rating your boat uses. The list comes from your passport. Before you put a spare in, check when a replacement is allowed (→ 4.8).
- **A marker and wire labels**: a circuit left unlabeled becomes an "unknown connection" in your own passport a year later.

What not to buy: an insulation tester (megger). Insulation testing lies beyond the line of → 1.8; why → 3.7.

> **NUMBERS · CLAMP METER ERROR**
>
> One DC clamp meter's data sheet gives its 60 A range as ±(2.0% + 8 digits), with a last digit of 10 mA: 80 mA of fixed error before the 2% is added. At a true 0.20 A the reading can be off by 0.084 A, which is 42%; at 1.00 A, by 0.10 A, which is 10%. MFR

LOOKS LIKE THE FIX	FIND OUT FIRST	WHAT FIXES IT
A clamp meter, because it shows where the current goes and will find what drains the battery overnight.	Think about what this book asks you to measure. "Where is voltage lost?" is a question a clamp meter does not answer, and a multimeter does (→ 3.4). Only a clamp meter marked for DC measures DC at all (→ 3.3). The current that drains a bank overnight is small. On an amps range of a general-purpose clamp meter, tens of milliamps are entirely inside its error; at hundreds of milliamps the error is	A multimeter connected in series measures the overnight drain, at the place and by the steps of the overnight-drain procedure (→ 7.3). A DC clamp meter is a second tool, bought after the multimeter, for loads measured in whole amps and for finding a load that draws amps when it should draw nothing.

	comparable to the reading — the number is in your meter's data sheet (→ 3.3).	

2.9. On board

ON BOARD: GOLDEN RULE

Count the sources before you count the devices. A device with no source is dead, and a source you did not list keeps its circuits live after you believe the boat is off.

What it means

Table 2.6. What it means

What you notice	What is happening	First check	Yourself or a pro
Every battery switch is OFF, and the bilge pump, the CO alarm or a clock still works	Those circuits are wired around the battery switches, straight to a battery; the switch does not disconnect them. A CO alarm can also run on its own internal battery	Follow each one's positive to the battery and find its fuse there, by looking. A CO alarm with no wire to a battery runs on its own battery: write that down. Write each one in the passport (→ 2.3 · p. 17)	**Do it yourself**

What you notice	What is happening	First check	Yourself or a pro
The bilge pump goes dead when every battery switch is OFF	The pump or its switch is wired after the battery switch: a boat left with the switches OFF has no automatic pump	Write it on the first line of the passport; how a pump and its switch are fed → 8.2, → 12.2	**Hire a pro: move the pump to a circuit wired around the battery switch, with its own fuse at the battery (→ 12.1)**
A heavy positive cable leaves the battery with no fuse or breaker	An unprotected positive: if its insulation wears through against metal, the battery drives current into the fault with nothing to stop it	 **BLOWN FUSE** Follow the cable with your eyes to where it ends. Of the wires that leave the battery, only the cable that carries the starting current from the battery to the starter, directly or through the battery switch, is the starter cable and needs no fuse; a wire taken off the starter's battery terminal to feed anything else is not (→ 4.2), and a jumper between the batteries of one bank is part of the bank (→ 6.4). Any other cable with no protection is an unprotected positive: write it on the first line of the Boat Passport (→ 2.1 · p. 2)	**Do it yourself, by looking; adding its protection: Hire a pro**
The battery monitor's percentage does not match what the batteries do	One cause you can see without a meter: a lead on the battery negative terminal bypasses the shunt, and the monitor never counts its current. The monitor's settings and its	Look at the battery negative terminal: one cable, to the shunt, is correct (→ 2.2 · p. 8, → 3.6); only the shunt cable is there → 7.6	**Do it yourself, by looking; moving a lead: Hire a pro (→ 1.8)**

What you notice	What is happening	First check	Yourself or a pro
	drift are the other causes (→ 7.6)		
A box with heavy studs between the batteries, and you do not know what it is	A relay, a diode isolator, a DC-DC charger or a solenoid: the case does not tell them apart	Read the maker and the model on the label and look up the data sheet (→ 2.2 · p. 8); until then treat its studs as live with every switch OFF	**Do it yourself**
A black wire behind the panel — is it the negative?	On the DC side black is a negative; in 120 V AC wiring black is the hot conductor. On a 120/240 V boat a red wire can be the second hot.	**SHORT CIRCUIT** **AC — PRO** Trace the wire to both ends (→ 2.4 · p. 22)	**Do it yourself, if... you follow its signs**
A yellow wire on a boat whose negatives are black	On a boat whose DC negatives are black, a yellow wire can be the bilge blower positive	The color is a hint; the proof is tracing the wire to both ends (→ 2.4 · p. 22)	**Do it yourself**
A green wire with a colored stripe	On a boat wired to the ABYC code, a green wire with a stripe of any color except yellow is trim or tilt power, not bonding.	Trace it to both ends: on a boat wired to the ABYC code, it ends at the trim or tilt motor, not at the bonding system (→ 2.4 · p. 22)	**Do it yourself**

What you notice	What is happening	First check	Yourself or a pro
Wire marked in mm², and a CE plate at the helm	A boat built to European rules: European wire sizes and colors, and a shore inlet that can be rated for another grid	Read the rating printed on the shore inlet and compare it with the pedestal's (→ 2.5 · p. 24)	**Do it yourself; an inlet that does not match the pedestal: Hire a pro**
The reverse polarity indicator is lit	The hot and the neutral of shore power are swapped somewhere between the pedestal and your AC panel	**SHOCK IN WATER** Unplug in the order of → 17.2; what the light means → 17.3	**Hire a pro**
The panel went dark on a charter or a friend's boat	A switch position, a tripped breaker, a discharged bank or a blown main protection	Follow the steps of → 2.7 · p. 33 in their order; on your own boat, the card "The panel went dark — no lights, no electronics" and → 19.6	**Do it yourself: switches and buttons only**
A battery smells of gas, is hot, hisses or swells; a lithium battery hisses, vents or swells fast	The battery is failing, and the gas it gives off can burn; a failing lithium cell vents gases that burn and are toxic	**HOT BATTERY** The card "Battery smells, is swollen, or is hot" (→ emergency card)	**STOP**
Water has reached the battery terminals	The flooding has reached the batteries	The card "Water in the boat — the pump can't keep up or is silent" (→ emergency card)	**STOP**

Do it yourself or hire a pro

DO IT YOURSELF OR HIRE A PRO · WALKING AND RECORDING YOUR BOAT

STOP · A battery that smells of gas, is hot, hisses or swells, and water that has reached the battery terminals: the walk-through stops there. The gas a failing battery gives off burns, and water at the terminals carries battery current.

What to do this minute: The card "Battery smells, is swollen, or is hot" (→ emergency card) or the card "Water in the boat — the pump can't keep up or is silent" (→ emergency card).

HIRE A PRO · Any wrench at the battery (→ 1.8), except the planned job on a battery (→ 6.5). A wrench that touches the positive and the negative, or the positive and the engine block, at the same time shorts the battery, and the current is limited only by the battery itself. Adding protection to an unprotected positive, work on the main protection of a bank, and moving a bilge pump wired after the battery switch to a circuit wired around it are also a pro's work.

Ask the pro to size the protection at the battery by the triad (→ 4.3) and to place it by the rule of → 4.2; on a lithium bank, ask about the interrupting rating of the main protection (→ 11.2). Accept the work by the three signs under "What to tell the pro", below.

If no pro is available:  **BLOWN FUSE** Until a pro comes, an unprotected positive and a bank's tripped or blown main fuse or breaker are handled as this sign's entry says (→ 1.8).

When a pro may do it differently: A pro can choose a rating above the triad where 33 CFR 183.455(c) or ABYC E-11 allows it, never above the device maker's rating: the allowance is for the wire only. You see it this way: the pro names the clause, and the entry in your passport says what was done and why.

DO IT YOURSELF, IF…

The walk-through, with the signs at the start of its seven stops; its last stop turns every battery switch OFF to find the circuits wired around the switches (→ 2.1 · p. 2). Tracing a wire behind a panel, with its signs (→ 2.4 · p. 22).

DO IT YOURSELF · Without opening a compartment: the labels you can read, the HIN and the plates, the passport and the one-line diagram.

On someone else's boat there are three levels, not four: switches and buttons — yes; tools — no; the gray zone — only with the permission of the charter base or the owner, by phone. (→ 2.6 · p. 28)

What to tell the pro

WHAT TO TELL THE PRO

"Please trace the DC system from each bank to the panel, and mark on my one-line diagram every unprotected positive and every circuit wired around the battery switches. Install protection at the battery on the circuits I marked: the rating by the load current, the thinnest wire of the circuit and the device maker's limit." You accept the work by three signs. The rating is readable on the holder and passes the triad — or the pro names the clause of 33 CFR 183.455(c) or ABYC E-11 that allows a higher rating, never above the device maker's rating, and it is written in the Boat Passport. Each fuse or breaker sits within the distance from the terminal that → 4.2 allows, and the distance is measured. The type, the rating and the distance are in your passport the same day.

For a European-built boat: "The boat was built to European rules — CE plate, wire marked in mm², shore inlet rated ___ V, ___ Hz. Tell me where its factory wiring differs from ABYC E-11, what you would change for use at US docks, and why." You accept the answer when you have a written list of the differences, with a reason for each change.

REMEMBER

- Count the sources first: each bank, each shore inlet, the inverter, the generator, solar panels, a wind generator, and the alternator of a running engine.
- A battery switch disconnects only what is after it. The battery terminals, the cables up to the switch and every circuit wired around it stay live in every position.

- What still works with every battery switch OFF is wired around the switches, and each such circuit needs its own fuse at the battery (→ 2.1 · p. 2).
- The color is a hint; the proof is tracing the wire to both ends. On a boat whose DC negatives are black, a yellow wire can be the bilge blower positive. On a boat wired to the ABYC code, a green wire with a stripe of any color except yellow is trim or tilt power, not bonding. A black wire can be the hot conductor of 120 V AC wiring. On a 120/240 V boat a red wire can be the second hot.
- On a boat built on or after August 1, 1984, the HIN has 12 characters; "US-" in front of it is not part of it; the last two characters are the model year.
- A CE plate, a CIN and wire marked in mm² are clues to a European-built boat, not proof of its wiring today; the rating printed on the inlet tells whether it suits the pedestal (→ 2.5 · p. 24).
- On someone else's boat there are three levels, not four: switches and buttons — yes; tools — no; the gray zone — only with the permission of the charter base or the owner, by phone. (→ 2.6 · p. 28)
- In the passport, "don't know" is a valid answer, and a connection you did not trace is not drawn.
- In a shunt with electronics, no current of the loads flows in the thin wires; anything connected on the battery negative terminal bypasses the shunt, and the monitor does not count it.

Self-check

1. **Before you look at the monitor.** Suppose a charger's negative lead lands directly on the house battery's negative terminal, bypassing the shunt, and the charger puts 10 A into the bank for five hours while every load is off. Decide first: how many amp-hours will the battery monitor show going into the bank?

   Answer: 0 Ah. All 50 Ah (10 A × 5 h) went in through the charger's negative lead,

which does not pass through the shunt; the monitor counts none of it (→ 2.2 · p. 8).

2. **Your turn.** The DC-DC charger of the worked example (→ 2.3 · p. 17) delivers 30 A at an efficiency of 87%, and this time its input and output voltages are equal. Before you calculate: is the input current more or less than 30 A, and by how much?
   Answer: more, by about 4 A: 30 ÷ 0.87 = 34 A. The input cable and its fuse still come from the maker's manual (→ 2.3 · p. 17).
3. **Read a HIN.** Suppose the last four characters of a HIN read K809. In which month and year was the hull built, and what is its model year?
   Answer: K is the eleventh letter, so November; 8 is the last digit of the year built, and the model year 09 (2009) places it at 2008. The boat was built in November 2008 as a 2009 model. This reading holds for boats built from August 1, 1984 (→ 2.5 · p. 24).
4. **A yellow wire.** A yellow wire runs from a panel switch labeled BLOWER to the bilge blower, and every other negative on the boat is black. Is the yellow wire a negative?
   Answer: no. On a boat whose DC negatives are black, a yellow wire can be the bilge blower positive. The color is a hint; the proof is tracing the wire to both ends (→ 2.4 · p. 22).
5. **Someone else's boat.** On a charter boat, the ELCI tripped when you plugged in. Are you allowed to reset it?
   Answer: yes. It is reset with a button or a handle, and you handle it as on your own boat, by the card "Shore power tripped and won't come back on" (→ emergency card). Then tell the base what tripped and what you did (→ 2.6 · p. 28).
6. **A dark charter boat.** The panel went dark at the dock with the engine stopped, and the battery switch is on 1. Are you allowed to try BOTH to bring the panel back?
   Answer: not before steps 3 and 4 of 2.7 have found the main panel breaker and the main protection intact, and then not without the base's permission, because BOTH joins the banks directly, and so does a parallel switch or a charging relay's own combine control ON. Call the base. The switch goes only to the position you recorded at check-out (→ 2.7 · p. 33).

7. **On your boat.** Take the walk-through to its seventh stop (→ 2.1 · p. 2), and write down everything that still works with every battery switch OFF. Then find the fuse of each item at the battery, by looking.

   Answer: every item on your list is a circuit wired around the switches, and each one needs its own fuse at the battery; an item without one goes on the first line of the passport. The last block of the walk-through puts every switch back.

8. **On your boat.** Find the HIN on the transom and write down every character, with "US-" or a country code if one stands in front. Read the month, the year digit and the model year. Then find the capacity plate or the builder's plate, and write the "how the boat was built" line of your passport: US plates, CE plate, both, or don't know.

   Answer: a 12-character number and US plates: US-built. A country code, a hyphen and a CE plate: built to European rules, whatever the code. US plates and a CE plate: mark both. Neither: "don't know" is a valid answer (→ 2.5 · p. 24).

9. **On your boat.** Look at the house bank's negative terminal and write down every lead that lands on it.

   Answer: one cable, to the shunt, is correct. Any other lead on that terminal bypasses the shunt, and the monitor does not count its current; moving it is work at a battery terminal (→ 1.8).

Terms

hull identification number (HIN)
The 12-character number of a boat built or imported for sale in the US: maker's code, serial number, month and year built, and model year.

craft identification number (CIN)
The identification number of a boat built to European rules: the maker's country code, a hyphen, and 12 characters in the order of a HIN.

CE plate
The builder's plate of a boat built for the European market, with the CE mark, the design category, the maximum load and the number of persons.

design category (A, B, C, D)
A letter on a CE plate that describes the wind and waves a boat was designed for, not its electrical system.

capacity plate
The plate that gives the maximum persons, weight and, on an outboard boat, horsepower; required only on monohull boats less than 20 ft long, with exceptions.

Boat Passport
Your record of the boat's electrical system: a one-line diagram and a set of fields, updated after every accepted job.

one-line diagram
A diagram that shows each positive connection of the boat as one line, from the sources on the left to the loads on the right.

circuit wired around the battery switch
A circuit connected on the battery side of the switch, so it stays live in every switch position; it needs its own fuse at the battery.

automatic charging relay (ACR)
A relay that joins two banks while it senses charging voltage and separates them when the voltage falls.

diode isolator
A unit that lets current flow from one alternator (or two) to two or three banks and never between the banks.

DC-DC charger
An electronic charger that takes power from one bank and delivers a controlled charge to another.

inverter/charger
One unit that charges the batteries from shore power and makes 120 V AC from the batteries when shore power is gone.

shunt
A calibrated resistor in the main negative cable whose small voltage tells a battery monitor the current; rated in amps and millivolts.

bus bar
A metal bar with several studs or screws that joins many wires at one point.

main protection
The fuse or breaker nearest a bank's positive terminal, which protects the cable that leaves the bank.

interrupting rating (AIC)
The largest current a fuse or breaker can interrupt at its rated voltage and stay intact.

ELCI
A breaker on the boat's shore power that also trips on leakage current; like every protective device, it is recognized by its TEST button.

galvanic isolator
A unit in the green grounding conductor of shore power that blocks small DC currents in that conductor.

alternator field disconnect (AFD)
An extra contact on some battery switches that opens the alternator's field circuit slightly before the main contacts open.

gray zone (on someone else's boat)
Anything you are not sure is a switch or a button; on someone else's boat, only with the permission of the charter base or the owner, by phone.

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