Understanding electrics: boat wiring explained

Pat Manley and Oliver Ballam demystify boat electrics and explain wiring and the best techniques for its installation

Electrical wire used on boats should be tinned (covered in solder) along its whole length. This is expensive, so most production boats have 'automotive-type' wire, which allows corrosion to spread along the strands of wire under the insulation.

This makes it impossible to remake joints successfully. Where one end of a wire is located in a damp atmosphere, tinned wire should always be used.

Unless it's unavoidable, don't run wires through the bilge where their condition will deteriorate.

ABOVE Beta duct trunking

ABOVE Ducting to protect insulation

Running wiring

Use a push wiring threader to run wires through conduits and pipes.

1. Insert one end into the conduit or gap through which you need to run the wire.
2. Then push the threader through.
3. Then use the threader to pull the electric wire all the way back through.

If you need to run wires straight through inaccessible spaces then draw rods are better because they are rigid and you can angle them to come out of, or go into, a space. They screw together and can be assembled 'as you go'.

Most alloy masts have internal conduits, provided to carry wiring running up the mast. Sometimes these are extruded as part of the mast and sometimes they are plastic conduits clipped or riveted onto the side of the mast. Wires dropped through the main section of the mast will slap and chafe.

A push threader can be used to run mouse lines and cables up the mast's conduit. If possible, it's usually easier to pull one existing cable back with a mouse line attached, and then attach the new cable and the old cable together to the mouse line.

Tips

1. Run a mouse line in case you need to run another cable later. The mouse line can be run through the conduit (or other routes where a cable is run) at the same time as you install a cable. The mouse line is then left in place for the next time you need it. The mouse line should be twice as long as its route, so that you don't pull it all the way through when you use it.
2. Use grommets or clips on ducting to protect the insulation where you run wires through bulkheads, etc.
3. Support cable runs regularly along their length.
4. Cable should not come under strain, which could cause connections to be pulled apart.
5. A very neat and secure way to protect and support cables is to run them in corrugated trunking. If cables are already in place, split trunking is available that can be placed around the cables in situ. This also improves the aesthetics of the wiring run.
6. If you need to run cables to terminals mounted on a flat surface, use 'Beta duct' trunking, which has holes and slots. This is a very good way to organise and support the cables and they can exit through the slots to their relevant terminals or equipment.
7. Make a wiring diagram of any new work to be stored with the boat's manual. If there are joints/junctions access points, try to indicate on the diagram where these points are.

ABOVE A set of draw rods

Heavy-duty circuits

A DC electric motor will overheat and suffer early failure if the supply voltage is reduced. Motors with high current requirements need special care with their wiring circuits to maintain an adequate voltage. Normally, a voltage drop of 10% is the maximum allowed.

The operating switch will not handle the required current, so a relay is introduced into the circuit. A relay consists of an

ABOVE Grommets to protect insulation
LEFT: Inserting a draw rod

RIGHT Tinned marine wire

BELOW Automotive-type wire

'Make a wiring diagram of any new work to be stored with the boat's manual'

electromagnet that can be operated by the low current; its contactors then carry the high current required to operate the motor, or whatever.

This keeps the switching current low, but heavy-duty contacts handle the high current load of the motor. Proper siting of the relay will keep the length of the high-current circuit to a minimum.

Let's see why an electric windlass, for instance, might fail prematurely if its wiring has too much resistance:

Say it has a maximum power of 1,000W and should be run at 12V:

- The current would be 83.33A at maximum pulling power: **1,000W ÷ 12V = 83.33A**
- Say the resistance of the wire is such that there is a 10% voltage drop: **2V x 90% = 10.8V**
- The current would now need to be 92.59A if required to pull its maximum load: **1,000W ÷ 10.8V = 92.59A** because it would try to maintain power by drawing more current from the battery at the reduced voltage
- With a 20% voltage drop (to 9.6V), the current would be 104.2A: **1,000W ÷ 9.6V = 104.17A**
- This would give a 25% current overload: **104.17A ÷ 83.33A = 1.25** leading to rapid failure

For the same reason, if you had the engine running, the voltage at the windlass would be about 13.5V. With the engine stopped and the battery down from overnight use, the windlass voltage could easily be reduced to 10V or so.

Engine running:
1,000W ÷ 13.5V = 74A

Engine off:
1,000W ÷ 10 V = 100A

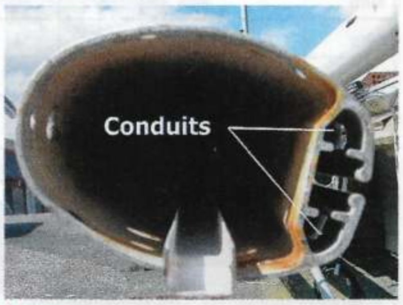
Which windlass motor is going to last longer?

You might think that the windlass motor is a fixed resistance so by Ohms Law, as the voltage decreases, so does the current. However, motors produce something called back EMF (voltage) which acts against the current flow. This means that the operating current is optimal at rated speed. It's at its highest when the motor is stationary. Back EMF is too detailed to discuss here, but it's why poorly supplied motors fail early.

Starter motors and sheet winches

These are operated with the engine stopped. Starter motors normally run ➔

ABOVE Corrugated trunking



ABOVE An alloy mast with conduits

RIGHT Supported cable

for a very short time and have a relatively short run of very heavy cable. Provided connections are clean and well made, they make only small demands on a dedicated engine start battery.

Sheet winches may have relatively long cable runs and the demands on the battery system can be significant, so that voltage drop at the motor needs to be minimised. Adhere strictly to the manufacturer's wiring requirements.

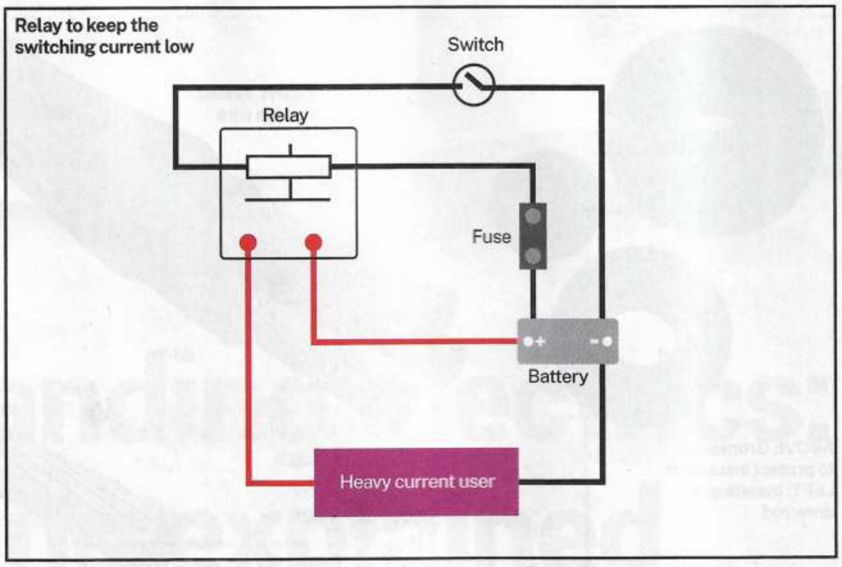
Bow thrusters and anchor windlasses

To keep voltage drop to a minimum, these are normally used with the engine running to prolong the life of their electric motors and to minimise battery drain. Bow thrusters especially can't be powered directly from the engine alternator, as it won't produce enough current.

There are two schools of thought on powering these machines:

1. An existing battery – engine or domestic

Long, very heavy and expensive cables run from the aft battery bank. For a bow thruster these cables may carry 400A and may have a circuit length of 20m, in which case a cross-sectional area of 200mm² may be needed for cables. That's a diameter of 16mm! Windlass cables will be appreciably smaller as most windlasses draw more like 80-100A (typically 35-70mm²). If no bow thruster is installed this is the most common method for a windlass.



2. A separate battery close to the demand

The heavy cable length is kept to a minimum by placing a dedicated battery close to the windlass or bow thruster. This is charged by a smaller cable from the engine/charger. The charging cable needs to be rated to carry the maximum charging current and associated voltage drop only. The lower cost of the lighter cable, however, may be outweighed by the cost of the extra battery.

The disadvantage of this method is the weight of this battery forward in the boat, although the total weight of cable and battery may be similar for both methods. It also complicates the charging system significantly, but this is the favoured option for bow thrusters.

Wire current rates

A wire must be capable of carrying the maximum current in the circuit. All wires have a current rating. A 5A wire must carry no more than 5A, and so on. Note that wires bundled together can carry less current because they will heat up.

Wiring for sensitive equipment should not allow more than a 3% voltage drop. Normally this is more restrictive than the current rating because it depends on the length of the wires (both positive and negative).

Other wiring may be allowed a 10% voltage drop along its total length. Even 10% will usually require a larger diameter of cable than the current carrying capacity. The cable should be specified to suit the largest requirement.

12V circuits will always require heavier cable than 24V circuits, because with 24V the current is halved for the same power appliance. This is why larger boats (with

Wire size 3% voltage drop
(Critical applications – bilge pumps, navigation lights, electronics, etc.)

	Current								
LENGTH	5A	10A	15A	20A	25A	30A	40A	50A	100A
5m	16	12	10	10	8	8	6	6	2
10m	12	10	8	6	6	4	4	2	1/0
20m	10	6	6	4	2	2	1	1/0	4/0
30m	8	4	4	2	1	1/0	2/0	3/0	
40m	6	4	2	1	1/0	2/0	3/0	4/0	
50m	6	2	1	1/0	2/0	3/0	4/0		

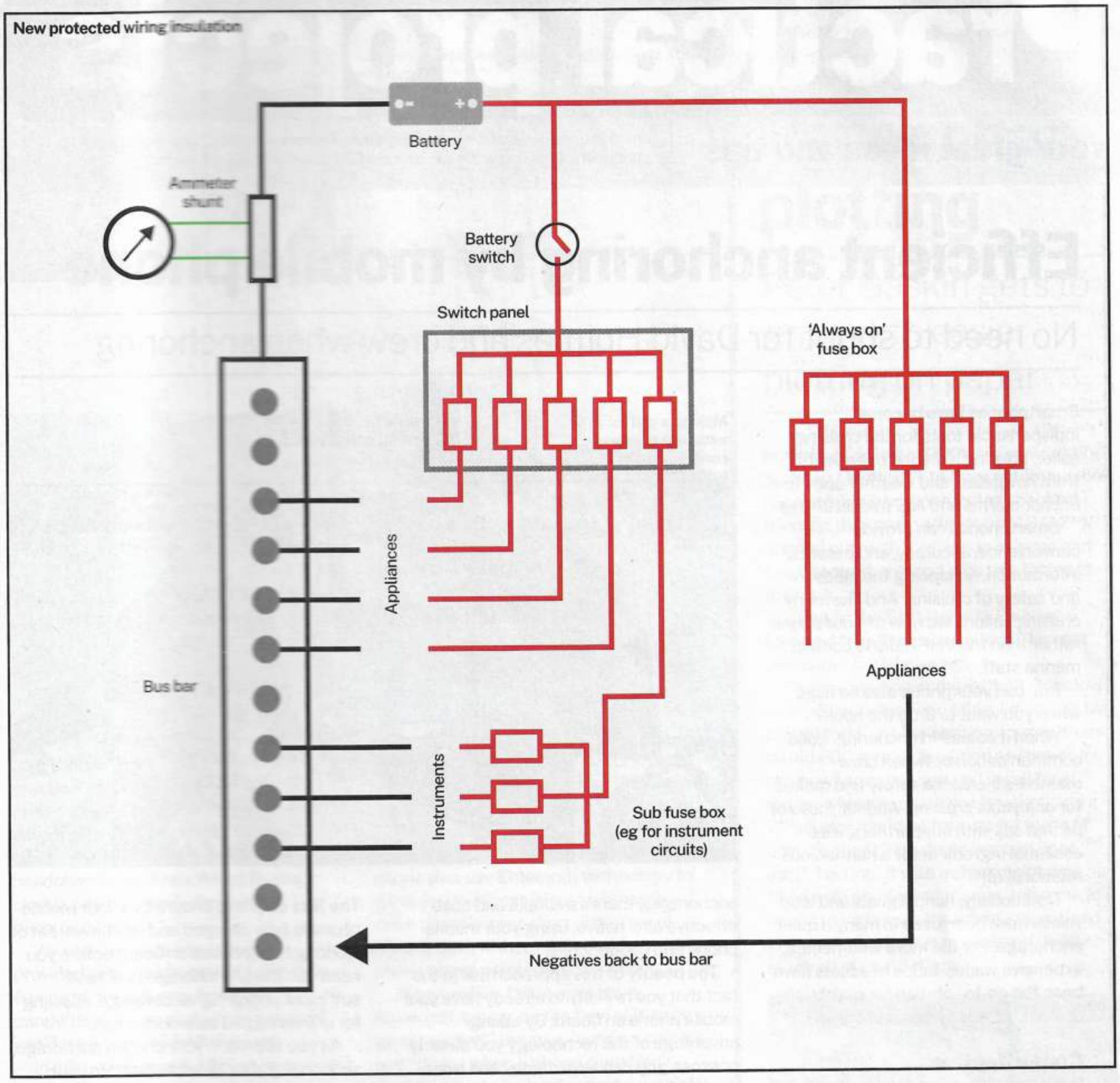
Wire size 10% voltage drop
(Non-critical applications – windlasses, cabin lights, etc.)

	Current								
LENGTH	5A	10A	15A	20A	25A	30A	40A	50A	100A
5m	18	18	16	16	14	14	12	12	6
10m	18	16	14	12	10	10	8	8	4
20m	16	12	10	8	8	8	6	4	2
30m	14	10	8	8	6	6	4	4	1
40m	12	8	8	6	4	4	2	2	2/0
50m	10	8	6	4	4	2	2	1	3/0

American wire gauge 'boat cable'

AWG	18	16	14	12	10	8	6	4	2	1	1/0	2/0	3/0	4/0
mm²	0.8	1	2	3	5	8	13	19	32	40	50	62	81	103
Max. amps	20	25	35	45	60	80	120	160	210	245	285	330	385	445

Reduce current by 15% when run in engine compartment.
Standard UK wire sizes – 1, 1.5, 2.5, 4, 6, 25, 35, 50 and 70mm².



longer runs and heavier loads) will run a 24V system.

Wire sizes required for a given length of cable run

(Length is the sum of the positive and negative wires) - see tables opposite

When installing new equipment you'll need to:

1. Decide where you will need to power the equipment from
   - The battery (if it needs to be on all the time)
   - The battery isolator (best if it is turned off by the battery isolator)
   - An existing bus bar or circuit breaker.

2. Check the wire size required, according to its length and the current it has to carry, from the table above.
3. Run a new positive wire from the above source to a fuse holder or circuit breaker.
4. Run a new positive wire from the new fuse holder to the new equipment.
5. Run a new negative wire from the existing negative bus bar or a new one as appropriate.
6. Once you've checked your work, fit an appropriately-sized fuse, as recommended by the equipment manufacturer.

Note:

- The fuse or circuit breaker should be fitted as close as practicable to the positive source.
- If you have an ammeter, its shunt should be fitted in the negative battery cable.
- Equipment supplied direct from the battery MUST have the negative cable connected via the shunt and NOT taken direct to the battery's negative terminal.
- If you are planning to add more than one device, you may need to add a positive and/or negative bus bar.
- When connection to the battery is necessary, some vessels will have a bus bar already – can you connect to this rather than adding more wires to the battery? Is the bus bar and supply wiring capable of carrying the extra current? PBO

ABOUT THE BOOK

The third edition of Essential Boat Electrics (Fernhurst Books, £16.99) is available at fernhurstbooks.com.

Written by Oliver Ballam and the late Pat Manley, it's a practical guide – with simple language and clear diagrams – to allow owners to tackle electrical jobs on board. There are tutorials, from wiring a circuit, to troubleshooting electrical faults, all using easy-to-follow photo sequences. The book also looks at tasks such as choosing solar panels and batteries and connecting navigational instruments.