OUTBACK MARINE

www.outbackmarine.com.au

Power Distribution, Management and Control of Lithium Batteries

Experienced cruisers know that a good electrical system is at the top of the list when it comes to hassle free boating or camping. The 12 or 24 volt battery system supports an extensive array of equipment. For those who are setting out to do a new electrical installation or refurbish an old, the best advice is to get it right the first time.

Lithium Ion batteries are a talking point in the marine and RV world as they offer substantial benefits over their lead acid battery counterparts. They also present new challenges in the area of power distribution and battery management. As with anything new, opportunistic marketeers are quick to offer product without thinking through the overall system aspects. This paper identifies some key aspects of power distribution and offers a solution that is in step with Lithium battery technology.

Electrical System Overview

At the core of the system is a DC (direct current) battery-based power system to supply all major vessel loads, which may include engine starting, anchor windlass, pumps, lighting, electronics, communications, navigation equipment, refrigeration, desalination and entertainment systems.

Energy to power these systems is stored in a battery bank that allows the DC system to provide power at any time without the need to have a power generation source available at any particular time. With the right design and product selection, an engine-driven power source might only need to run for one hour each day - or significantly less if sufficient solar and/or wind power is available.

The diagram at right shows an example of a fairly advanced boat electrical system. Power distribution is divided between DC power (12 or 24 volt) and AC power (240 volt/50 Hz). Power sources connect to either DC or AC power distribution services.

DC Power Distribution

Batteries, anchor windlass, engine starting, inverter charger, cross charging and electrical panels are high power consumers and/or producers of electrical energy that require special attention to ensure safe and reliable operation. The interconnection, circuit protection, control and monitoring of these devices is the realm of heavy power distribution.

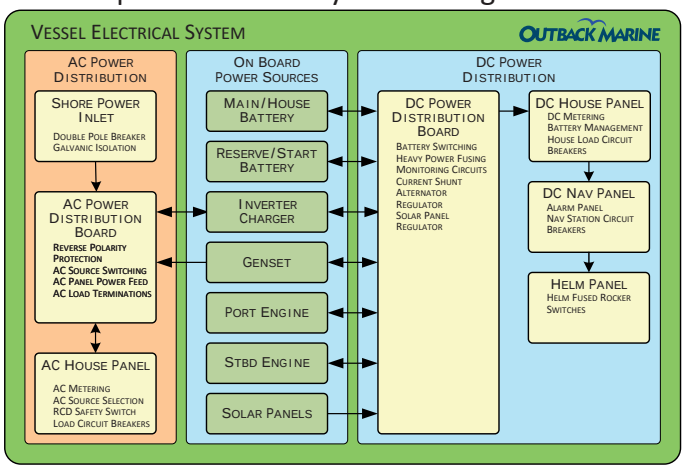
All electrical circuits require protection against overload and short circuit conditions. The heavy cable that is used for interconnection of this equipment ideally suits a bus bar configuration with integral fuse protection of each circuit. Outback Marine has developed a range of DC Power Distribution Boards (DCD's) that facilitate the interconnection, circuit protection, control and monitoring functions in a compact and reliable manner.

The DCD board is central to the entire electrical system. By planning the placement of equipment in close proximity, cable runs are kept short and power losses are minimized. Available boards range from simple manual battery switching versions through to remote controlled solenoid models with advanced monitoring and control capability.

The arrangement of the DCD board and electrical system in general depends on the vessel configuration with variables that may include the following.

- Type of application - yacht, power boat, RV, caravan, industrial etc.
- Engine charging system
- AC generator system
- Solar panels and wind generation
- Battery technology

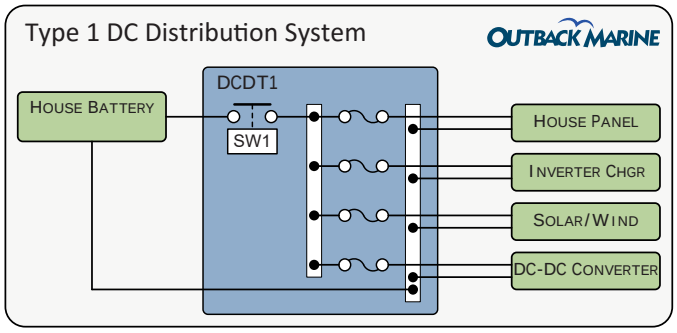
One system doesn't fit all situations however most applications fit into one of five different DC distribution system arrangements. Each of these differ in their approach to battery management and their demand placed on battery monitoring and control.



The DC Power Distribution Board is at the core of the electrical system distributing power between all heavy current devices. It includes battery switching, bus bar based power distribution and fused circuit protection.

Type 1 DCD System

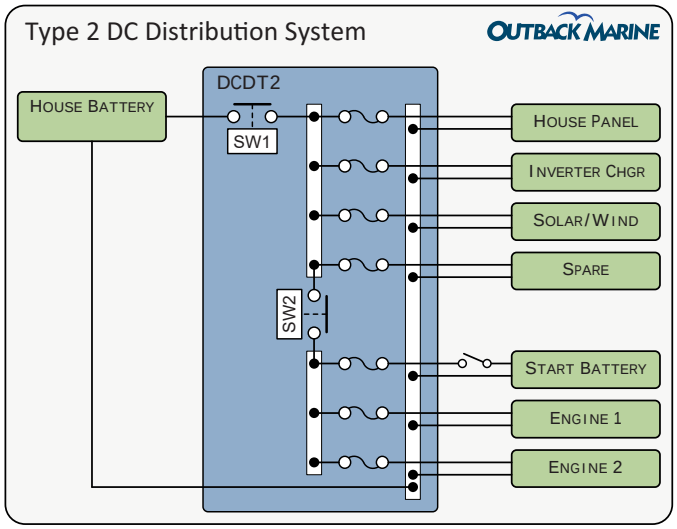
This board supports a system that has only a single house battery bank. A battery switch is used to isolate the battery from the system in case of an emergency situation - for example an electrically driven fire caused by a short circuit. Fuses mounted on the positive bus bar protect outgoing circuits. A negative bus bar provides a ground return path.



Commonly used for caravan and trailer installations, a DC-DC converter is used to charge from a vehicle starting battery over long cable runs.

Type 2 DCD System

The type 2 system adds a second switch that connects the house battery positive distribution bus to a an engine system or alternate charging system. The switch can perform the function of a cross charging relay that allows the house battery to be charged from the engine source. The switch would open circuit when the engine stops to prevent discharging the starting battery.

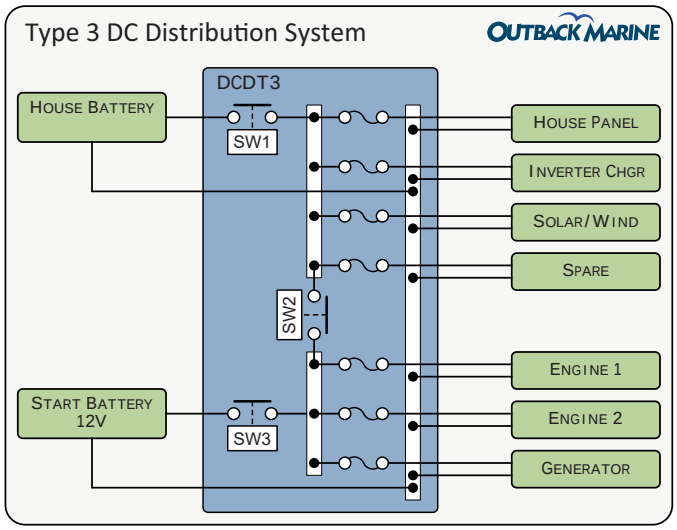


This type of system is used when an engine alternator is used for house battery charging. The house battery can also back up the cranking battery if ever required. It's the system of choice where a relative short and heavy cable run can be made to the engine - for example RV's and vans and 4WD's. It also works for upgrading boats where an existing engine cranking system already exists.

Type 3 DCD System

The type 3 system adds an on-board switch for the start/reserve battery. This system can keep track of the reserve battery state of charge and temperature so that the battery can be used as an alternate house source in case of a battery shutdown.

It has the possibility of bringing in the reserve battery to power the house system before taking the house battery off line. This is a much better situation instead of just taking the house battery off line without notice.

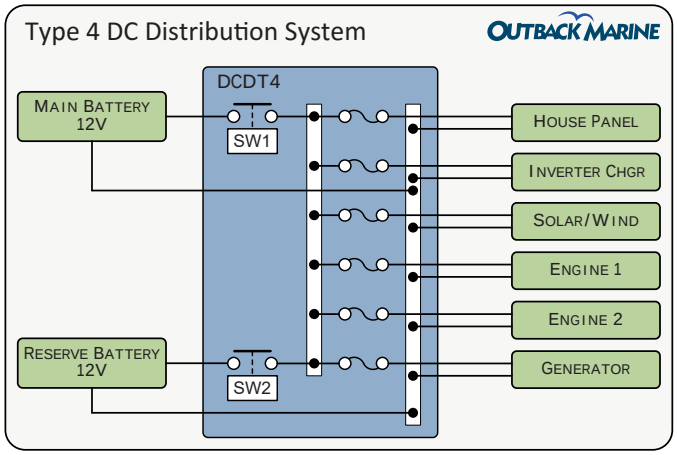


This is the system of choice for inboard and outboard powered cruising vessels where a Lithium Ion house battery can be combined with an AGM starting/reserve battery.

An electrical system cabinet on a Lightwave 38 sailing catamaran houses the electrical panels, Type 3 DCD Board, Inverter Charger and Solar Regulator. The DCD board is central to most heavy current devices.

Type 4 DCD System

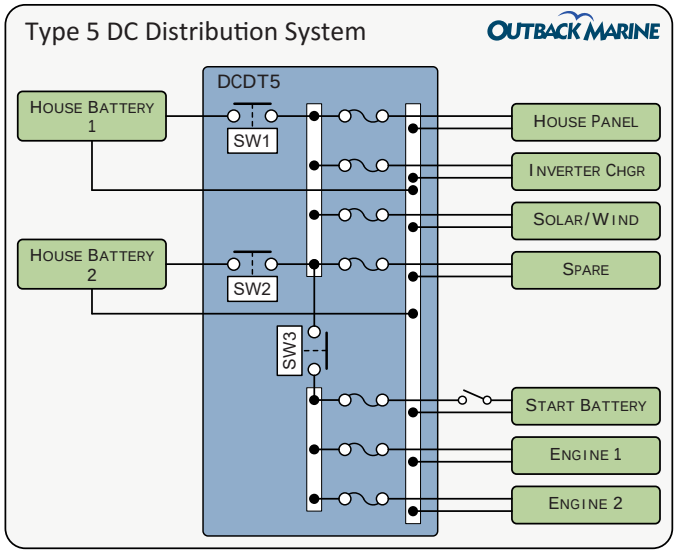
Type 4 systems have an alternate approach to battery organization. Two batteries connect to a common DC distribution bus. They can be used together or separately for both house and engine cranking applications. They should be both of the same chemistry but do not need to be the same size.



This is an ideal system for a high reliability Lithium Ion battery system. Normal operation would share both batteries however a BMS (battery management system) fault on one battery would still leave the other battery immediately available.

Type 5 DCD System

The type 5 system extends on the Type 4 by adding a separate engine/charging bus. It's similar to a Type 3 system with the addition of a second house battery.



This system would be ideal for a larger vessel or motor home application where a redundant house battery system is combined with a cross charging capability with the engine alternator.

Battery Monitoring

Batteries are charged when a power source is available. They provide energy on demand at any time irrespective of other power sources. Solar power happens on its own timetable however an engine might be started for the sole purpose of battery charging. Battery monitoring allows us to manage the energy we have left in the battery and determine when to start and stop charging.

State of Charge (SOC) represents the charge level. It's calculation is based on the total battery capacity and the accumulation of amps flowing into or out of the battery. It can be expressed as a percentage of full or as remaining amp hours.

Monitoring systems keep track of the key parameters and provide a warning or possibly shut down a system when dangerous conditions are imminent.

Performance trends allow an analysis of past performance which can be used to fine tune system operation. High performance systems that minimize battery capacity rely heavily on battery monitoring to work closer to the battery limits. This is particularly true for Lithium Ion systems.

Lithium Ion Battery Management

Although Lithium battery technology delivers outstanding performance, it also requires a higher level of diligence in it's operation. An accidental over discharge or charge can cause severe cell damage.

Battery management systems (BMS) monitor battery parameters and act accordingly to protect the battery. The action might vary according to the fault. For example a battery that is approaching a state of charge limit might turn off non essential loads. Or a high cell voltage warning might cause a momentary shutdown of a charging source. Ultimately the BMS can act directly on the main battery switch and isolate the battery to prevent damage.

Some applications may sustain an unscheduled battery failure but others would not be able to cope with an unscheduled blackout. For example a vessel electrical system failure may be dangerous in some situations. Advanced BMS systems employ methods to bring on-line a reserve battery before taking the main battery off-line.

A Lithium battery and it's BMS needs to be part of the overall DC distribution system rather than just an add-on component. Utilizing a DC power distribution board with integrated Lithium BMS components is a commonsense yet economical approach.

There are three components to a lithium battery system.

- The lithium battery
- DC distribution board
- Battery Management System Controller

Together they provide a complete system solution.

Lithium Battery Pack

The Outback Marine Lithium battery pack is engineered for mobile applications. Cells are Lithium Iron Phosphate - a chemistry that's well recognized to be safe. The enclosure case is non conductive and the base is configured to allow bolting to a horizontal surface. Lifting slings ease transportation.

Tinned copper bus bars are used throughout for electrical connections and a Class T fuse is fitted at the positive terminal. Additional terminals are provided for capacity expansion. Cells are held under compression to immobilize them from vibration. Each cell is fitted with a balancing module that equalizes cell charge level at the top of each charge cycle. The modules use a simple analogue loop to signal that each cell voltage and provide a measure of battery pack temperature.

Quality is engineered into the battery. Cells are selected that are of near equal capacity. The battery is condition charged to ensure that all cells are in balance. Then a fully monitored discharge and charge cycle tests the battery pack capacity. During this test, all connections are checked for voltage drop and infrared imaging checks for any anomaly. Each battery is shipped with confidence.

The battery is engineered from the ground up with a practical view to mobile applications.

DC Distribution Board

The battery and cross charge switching use magnetic latching solenoids that don't consume current in either off or on states. The switching current for the solenoids is supplied by a driver board that receives commands from the BMS controller. All solenoids have a manual override that allows direct switching in case of an electronics failure.

Each battery input to the DCD is fitted with a digital shunt module that measures battery pack voltage, current, BMS status and battery temperature. This information is relayed to the BMS controller. Power and ground power distribution uses a bus bar arrangement. The positive distribution bus has dedicated terminal fuses for each high current circuit.

The house and starter batteries can be combined with a cross charge solenoid that can be controlled manually or act as an automatic charging relay.

Shown above is a Type 3 DC distribution board (DCDT3) that provides full monitoring and control of both house and start/reserve batteries. The start battery is fully monitored for use as a full reserve.

The Type 2 (DCDT2) board is typically used in conjunction with an existing engine/battery system. The start battery is monitored for voltage only.

Battery Management Controller

Some battery management systems only protect the Lithium battery from over and under voltage events. Others add cell based monitoring and cell balancing and may include a battery monitor as well. These are all good things.

However it's the electrical system that needs to be managed and not just the battery. Good engineering is about looking after things when something goes wrong. So when considering a Lithium system, it pays to look closer at what the BMS includes.

A comprehensive battery management system controller in conjunction with an integrated DC distribution system is a powerful combination.

- Monitoring and display of battery volts, amps, amp hours, temperature and solar amps with trend chart displays and historical data.
- Lithium Ion battery management including cell voltage monitoring and state of charge alarms.
- Manual and automatic control of battery switching and cross charge solenoid.
- Inverter and battery charger control.
- Separate charge bus control.
- Plain English language setup and operation.
- Internet web portal via Victron Color GX
- Bluetooth iPhone app. Android comig soon.
- NMEA-2000 battery data support (2016)

It's important to know whats going on.

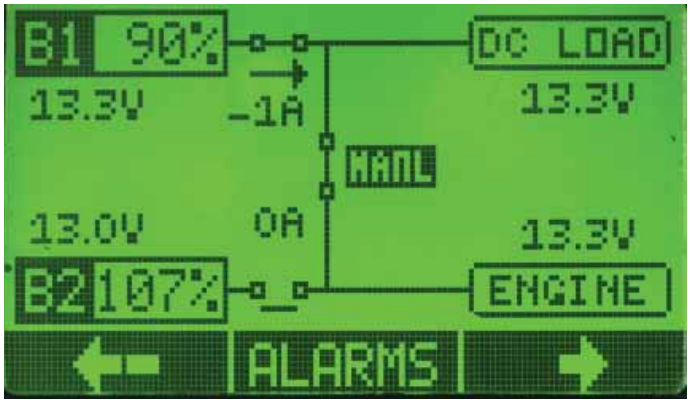
The Outback Marine battery management system uses an advanced controller with a graphic LCD display. This means that battery parameters can be displayed graphically over a time line that better indicates whats happening now relative to the past.

Following is just a sample of display capability.

A graphic display gives a true representation of the electrical system status.

A home screen button takes the user directly to a screen that presents an overview of the system that displays the overall system status.

- B1 and B2 battery state of charge, volts and amps (DCDT3 systems)
- B1 battery state of charge, volts and amps and B2 battery volts (DCDT2 systems)
- Battery switch status
- DC bus voltage



Battery switching is accomplished by pressing the associated battery switch button. The display will show the current battery status and present an option to change the switch status.

A comprehensive set of graphs show battery voltage, state of charge, amps and temperature for the last 2 minutes, 20 minutes and 1 hour, 4hours, 12 hours and 24 hours.