DC Main Circuit Protection and Branch Circuit Protection

Purpose

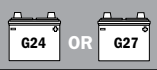
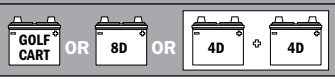
Fuses and circuit breakers are used to protect wire insulation from melting and starting fires in the event of over currents or short circuits which cause more amperage to flow in a wire than that wire is rated to carry. It is important to note that, except for those wires that are intended to carry starting currents, every positive wire in the DC Main Power Distribution System must be protected by a fuse or circuit breaker.

Considerations for DC Main Circuit Protection

Mounting Placement—distance from power source. The DC Main circuit protection system uses circuit breakers or fuses to protect the wires of the DC Main distribution system. The American Boat and Yacht Council (ABYC) publishes voluntary standards for the type and placement of the fuse or circuit breaker to be used as a DC Main circuit protection device. Note: Wire intended to carry engine starting currents between the batteries, the switch, and the starter is not required to have main circuit protection devices installed. Maximum mounting placement dimensions for a fuse or circuit breaker are 7" if the conductor is not housed in a sheath or enclosure in addition to the wire insulation, 40" if the conductor is housed in a sheath or enclosure in addition to the wire insulation, and 72" if the conductor is connected directly to the battery and housed in a sheath or enclosure in addition to the wire insulation.

Selecting DC Main Circuit Protection. The principal attribute of a DC Main circuit protection device is its Ampere Interrupt Capacity (AIC) rating. Specifications listed in the ABYC standards determine the AIC a DC Main circuit protection device must have. The required AIC rating is determined by the total CCA of the batteries connected to the circuit. See the tables below for the required AIC ratings.

ABYC Interrupt Rating Table

Total Connected Battery Cold Cranking Amperes (CCA) *		Ampere Interrupt Capacity	
12 VOLTS AND 24 VOLTS			
The white boxes identify two batteries, of the same size, placed in parallel configuration.		DC MAIN	DC BRANCH
	650 CCA or Less	1,500 AIC	750 AIC
	651–1,100 CCA	3,000 AIC	1,500 AIC
	Over 1,100 CCA	5,000 AIC	2,500 AIC
32 VOLTS			
	1,250 CCA or Less	3,000 AIC	1,500 AIC
	Over 1,250 CCA	5,000 AIC	2,500 AIC

* Battery cold cranking performance rating at -17.8°C (0°F): The discharge load in amperes that a battery at -17.8°C (0°F) can deliver for 30 seconds, and maintain a voltage of 1.2 Volts per cell or higher, (e.g. 7.2 Volts for a 12 Volt battery). The CCA for the battery icons in this chart is an approximation and could be slightly higher or lower. Consult the battery manufacturer's specifications for precise CCA ratings.

ABYC standard E-11 requires the use of circuit breakers that can be reused and reset and that they be applied as per the table above. The standard does not strictly require that fuses be applied in the same way, but it is an issue to consider, especially with high amperage fuses used to protect panel feeders or inverters. Fuses under 10 Ampere rating generally have such a high internal resistance they prevent fault currents from reaching 1000 Amperes in 12 Volt circuits. The apparent contradiction when using these fuses for bilge pumps and other circuits directly off the battery is less of an issue than it might seem. If a fuse blows, and the case appears to be cracked or metal has been ejected, the fuse holder should be replaced.

ABYC Ampacity† Rating Table

Allowable amperage for conductors under 50 Volts							Reference Data			
AWG Wire Size	Temperature Rating of Conductor Insulation									
	75°C (167°F)		90°C (194°F)		105°C (221°F)		Metric (Sq mm)	AWG CM Area	SAE CM Area	Ohms /1000ft
	Outside	Inside	Outside	Inside	Outside	Inside				
18	10	7.5	20	16.4	20	17	0.8	1,600	1,537	6.385
16	15	11.3	25	20.5	25	21.3	1	2,600	2,336	4.016
14	20	15	30	24.6	35	29.8	2	4,100	3,702	2.525
12	25	18.8	40	32.8	45	38.3	3	6,500	5,833	1.588
10	40	30	55	45.1	60	51	5	10,500	9,343	0.9989
8	65	48.8	70	57.4	80	68	8	16,800	14,810	0.6282
6	95	71.3	100	82	120	102	13	26,600	24,538	0.3951
4	125	93.8	135	110	160	136	19	42,000	37,360	0.2485
2	170	127	180	147	210	178	32	66,500	62,450	0.1563
1	195	146	210	172	245	208	40	83,690	77,790	0.1239
0	230	172	245	200	285	242	50	105,600	98,980	0.09827
2/0	265	198	285	233	330	280	62	133,100	125,100	0.07793
3/0	310	232	330	270	385	327	81	167,800	158,600	0.06180
4/0	380	270	385	315	445	378	103	211,600	205,500	0.04901

Wire selection for DC applications on boats is usually based on voltage drop requirements. However, there is a maximum continuous current that the wire can withstand without overheating. Higher grade marine wires are rated for service up to 105°C (221°F)—the ABYC wire capacity table for 105°C is most frequently quoted. The 105°C table accurately reflects the capacity of single conductors exposed to freely circulating cooling air. However, other factors, such as covering bundles of wire in outer jackets to form a cable, or use of conduits or structural voids to protect wires, can reduce the cooling and reduce the safe capacity of the wire.

A more conservative strategy is to use the 105°C wire, but treat it according to the 75°C table above when selecting circuit protection unless the wire is openly exposed for cooling.

See the Blue Sea Systems Circuit Wizard on our website at www.bluesea.com for more assistance with wire and circuit protection.

† Thermally limited amperage capacity

AC Main Power Distribution and Circuit Protection

Purpose

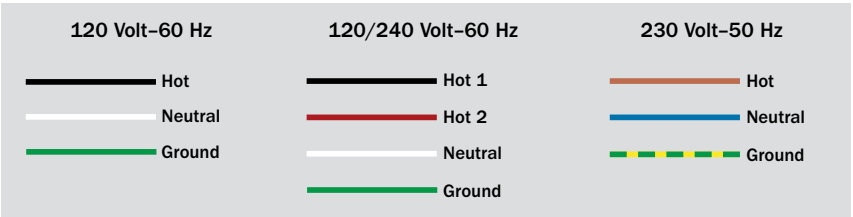
- Provide a path for delivering power from the ship's sources of AC power to the AC branch distribution system
- Provide a path for returning fault currents to ground via the green safety ground wire
- Provide a means for disconnecting AC power when the boat is not in use or in emergencies
- Provide electrical separation to insure that two sources of AC power are never connected
- Provide circuit protection for neutral and line wires in the AC main system
- Provide ground fault protection

Considerations for AC Main Circuit Protection

Due to the nature of alternating current, the devices used to distribute AC power are frequently the same as the devices that perform AC circuit protection. Before selecting components for an AC system, several important distinctions about AC power must be considered.

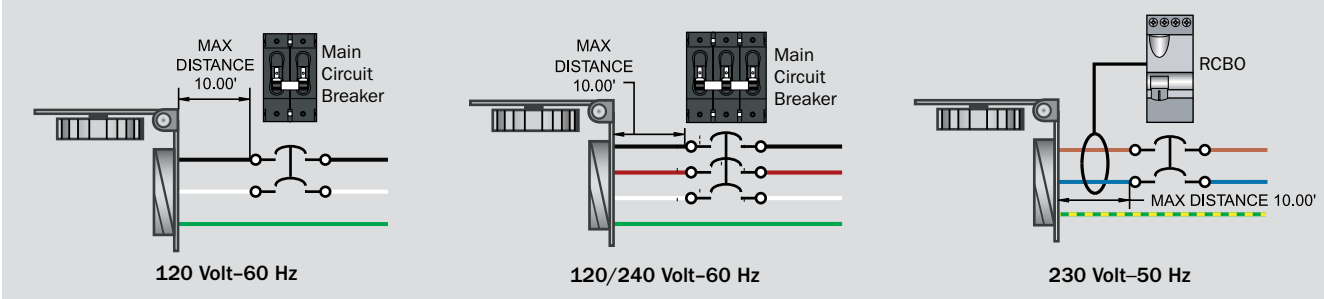
Direct Current (DC) vs. Alternating Current (AC). In DC systems, current flow is in one direction - from the point of higher voltage (electrical pressure) to lower voltage. In AC systems, the voltage reverses 60 times each second (50 times each second in Europe and other parts of the world), called "cycles" or "Hertz" (Hz). This voltage reversal also reverses the current flow and gives this type of power its name - Alternating Current (AC). Because of this alternating current and the higher voltages it uses, (120V AC and 240V AC at 60 Hz or 230V AC at 50 Hz vs. 12 or 24 Volts DC) the wiring configurations and components for AC current are different than DC.

AC Wire Systems. The three most common AC systems used on boats are shown below. In all cases the ground, sometimes called safety ground to clarify its purpose and differentiate it from the DC ground or negative, is said to be a "normally non-current carrying wire." Its purpose is to provide the lowest resistance path for AC currents that have strayed from their proper containment in the normally current carrying hot and neutral wires. The ground wire is connected to the exterior conductive parts of AC devices that could be touched by a person during normal operation and conducts errant AC currents safely to ground rather than passing them through a human body. The ground wire is never passed through a switch or circuit breaker.



Physical Configurations of AC Main Circuit Breakers. Sources of AC power, whether shore power or on-board generators and inverters, should always have a circuit breaker near the power source. This circuit breaker is designated the AC main circuit breaker. The AC main circuit breaker should always have a pole for each of the hot and neutral wires in the circuit assuring that circuit protection functions are not compromised in reverse polarity situations. Therefore 120 Volt systems use a double pole main circuit breaker. Although not required by the ABYC Standards, three pole circuit breakers with the Neutral connected through the third pole are sometimes used on 120/240 Volt systems. In cases where the main circuit breaker is also used for source selection, the Neutral must be switched to maintain the correct Neutral connection.

Physical Configurations of AC Main Circuit Breakers



Devices Qualifying as AC Main Circuit Breakers

In order to qualify as an AC main circuit breaker, four primary characteristics must be present:

1) The circuit breaker must have an Ampere Interrupt Rating (AIC) meeting those requirements of the table below.
2) The circuit breaker must be multiple pole, usually 2 or 3 (see "AC Wire Systems" above).
3) The circuit breaker must be rated for the appropriate AC system voltage in which it will be used.
4) The circuit breaker must be available in amperages appropriate to the design amperage of the system.
   In the USA, this is generally 30 and 50 Amperes, while European systems are generally 16 and 32 Amperes.

ABYC Interrupt Rating Table

AC Shore Power Source	Main Circuit Breaker	Branch Circuit Breaker
120V - 30A	3,000	3,000
120V - 50A	3,000	3,000
120/240V - 50A	5,000	3,000
240V - 50A	5,000	3,000

European systems also require that a Residual Current Device (RCD) be installed on the entire AC system. This is generally implemented as Residual Current Breaker Overload (RCBO) device which incorporates a double pole circuit breaker and an RCD into a single device.

Fuses and Fuse Blocks

DC Amperage Range

AGC/MDL Fuse—Appropriate for small electronic devices
Interrupting Capacity (I_{ic}): 1,000A DC **Maximum Voltage (V_{mxo}):** 32V DC

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ST Glass Fuse Block (6 Circuit Models Available)—Uses AGC/MDL Fuses
Maximum Voltage (V_{mxo}): 32V DC **Maximum Amperage (I_{mxo}) per circuit:** 30A DC **Maximum Amperage (I_{mxo}) per block:** 100A DC

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ATO/ATC Fuse—Appropriate for small electronic devices
Interrupting Capacity (I_{ic}): 1,000A DC **Maximum Voltage (V_{mxo}):** 32V DC

1-30

Available amperages (I_{tr})
1, 2, 3, 4, 5, 7.5, 10, 15, 20, 25, 30

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ST Blade Fuse Block (6 and 12 Circuit Models Available)—Uses ATO/ATC Fuses
Maximum Voltage (V_{mxo}): 32V DC **Maximum Amperage (I_{mxo}) per circuit:** 30A DC **Maximum Amperage (I_{mxo}) per block:** 100A DC

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MAXI™ Fuse—Economical high amp branch circuit protection
Interrupting Capacity (I_{ic}): 1,000A DC **Maximum Voltage (V_{mxo}):** 32V DC

30–80A

Available amperages (I_{tr})
30, 40, 50, 60, 70, 80

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MAXI™ Fuse Block—Uses MAXI™ Fuses
Maximum Voltage (V_{mxo}): 32V DC **Maximum Amperage (I_{mxo}):** 80A DC

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SEA Fuse—Appropriate for DC Main circuit protection with smaller battery banks or DC Branch circuits
Interrupting Capacity (I_{ic}): 2,000A DC **Maximum Voltage (V_{mxo}):** 32V DC

100–300A

Available amperages (I_{tr})
100, 125, 150, 175, 200, 225, 250, 300

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SEA Fuse Block—Uses SEA Fuses
Maximum Voltage (V_{mxo}): 32V DC **Maximum Amperage (I_{mxo}):** 300A DC

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Terminal Fuse—Appropriate for DC Main circuit protection at the battery post, battery switch, or terminal block
Interrupting Capacity (I_{ic}): 10,000A@14V DC/5,000A@32V DC/2,000A@58V DC **Maximum Voltage (V_{mxo}):** 58V DC
IP Meets Ignition Protection requirements

30–300A

Available amperages (I_{tr})
30, 40, 50, 60, 75, 80, 90, 100, 125, 150, 175, 200, 225, 250, 300

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Terminal Fuse Block—Uses Terminal Fuses
Maximum Voltage (V_{mxo}): 58V DC **Maximum Amperage (I_{mxo}):** 300A DC

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Class T Fuse—Appropriate for inverters and high amp equipment
Interrupting Capacity (I_{ic}): 20,000A DC **Maximum Voltage (V_{mxo}):** 160V DC

100–300A

Available amperages (I_{tr})
225, 250, 300, 350, 400

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Class T Fuse Block—Uses Class T Fuses
Maximum Voltage (V_{mxo}): 160V DC **Maximum Amperage (I_{mxo}):** 400A DC

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ANL Fuse—Appropriate for DC Main circuit protection
Interrupting Capacity (I_{ic}): 5,000A DC **Maximum Voltage (V_{mxo}):** 32V DC
IP 35–500 Ampere Fuses meet Ignition Protection requirements

Available amperages (I_{tr})
35, 40, 50, 60, 80, 100, 130, 150, 175, 200, 225, 250, 275, 300, 325, 350, 400, 500, 600, 675, 750

35–750A

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ANL Fuse Block—Uses ANL Fuses
Maximum Voltage (V_{mxo}): 32V DC
Maximum Amperage (I_{mxo}): 300A DC

ANL Heavy Duty Fuse Block—Uses ANL Fuses
Maximum Voltage (V_{mxo}): 32V DC
Maximum Amperage (I_{mxo}): 750A DC

Thermal Circuit Breakers

AC Amperage Range | DC Amperage Range

Page 38

Push Button Reset-Only—Appropriate for 24-hour circuit protection
Interrupting Capacity (I_{ic}): 3,000A@14.7V DC/2,500A@28V DC **Maximum Voltage (V_{mxo}):** 32V DC
IP Meets Ignition Protection requirements
3–40
Available amperages (I_{tr})
3, 5, 7, 10, 15, 20, 25, 30, 40

Page 39

Medium Duty Push Button Reset-Only—Appropriate for 24-hour circuit protection
Interrupting Capacity (I_{ic}): 5,000A@32V DC **Maximum Voltage (V_{mxo}):** 32V DC IP Meets Ignition Protection requirements
15–60
Available amperages (I_{tr})
15, 20, 30, 40, 50, 60

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185-Series—Appropriate for DC Main circuit protection with battery banks under 1,100 CCA
Interrupting Capacity (I_{ic}): 3,000A DC@48V DC **Maximum Voltage (V_{mxo}):** 42V DC IP Meets Ignition Protection requirements
25–150
Available amperages (I_{tr})
25, 30, 35, 40, 50, 60, 70, 80, 90, 100, 110, 120, 135, 150

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187-Series—Appropriate for DC Main circuit protection with battery banks over 1,100 CCA
Interrupting Capacity (I_{ic}): 5,000A@12V DC / 3,000A@24V DC/1,500A@42 DC **Maximum Voltage (V_{mxo}):** 48V DC
IP Meets Ignition Protection requirements
25–150
Available amperages (I_{tr})
25, 30, 35, 40, 50, 60, 70, 80, 90, 100, 110, 120, 135, 150

Magnetic Hydraulic Circuit Breakers

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Residual Current Circuit Breaker (ELCI/RCBO), 1 and 2 Pole—Appropriate for ground fault and overcurrent trip protection
Interrupting Capacity (I_{ic}): 5,000A AC **Maximum Voltage (V_{mxo}):** 240V AC
15-30
Available amperages (I_{tr})
15, 30

Page 54, 72

A-Series Toggle, 1 Pole—Appropriate for AC and DC Branch circuit protection
Interrupting Capacity (I_{ic}): 7,500A@65V DC/3,000A@120V AC/3,000A@250V AC **Maximum Voltage (V_{mxo}):** 65V DC/250V AC
5–50A
Available amperages (I_{tr})
5, 8, 10, 15, 20, 25, 30, 40, 50

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A-Series Toggle, 2 Pole—Appropriate for 120V AC Main or 240V AC Branch circuit protection
Interrupting Capacity (I_{ic}): 3,000A@120V AC/3,000A@250V AC **Maximum Voltage (V_{mxo}):** 250V AC
10–50A
Available amperages (I_{tr})
10, 15, 16, 20, 30, 32, 40, 50

Page 54, 73

A-Series Flat and Restricted OFF Rocker, 1 Pole—Appropriate for AC and DC Branch and 24-hour circuit protection
Interrupting Capacity (I_{ic}): 5,000A@32V DC/3,000A@120V AC/1,500A@250V AC **Maximum Voltage (V_{mxo}):** 32V DC/250V AC
5–50A
Available amperages (I_{tr})
5, 8, 10, 15, 20, 25, 30, 40, 50

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A-Series Flat and Raised Rocker, 2 Pole—Appropriate for 120V AC Main or 240V AC Branch circuit protection
Interrupting Capacity (I_{ic}): 3,000A@240V AC **Maximum Voltage (V_{mxo}):** 240V AC
10–50A
Available amperages (I_{tr})
10, 15, 16, 20, 30, 32, 40, 50

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C-Series Toggle, 1 Pole—Appropriate for DC Main and AC and DC high load circuit protection
Interrupting Capacity: 10,000A@80V DC/5,000A@250V AC **Maximum Voltage (V_{mxo}):** 80V DC/250V AC
IP 100 Ampere Circuit Breaker (7250I) meets Ignition Protection requirements
5–100A
Available amperages (I_{tr})
5, 10, 15, 20, 25, 30, 50, 60, 80, 100

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C-Series Toggle, 2 and 3 Parallel Pole—Appropriate for DC high load circuit protection
Interrupting Capacity (I_{ic}): 5,000A@65V DC **Maximum Voltage (V_{mxo}):** 65V DC
Available amperages (I_{tr})
150, 175, 200, 250, 300
150–300A

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C-Series Toggle, 2 and 3 Pole—Appropriate for 240V AC Main and AC high load circuit protection
Interrupting Capacity (I_{ic}): 5,000A@250V AC **Maximum Voltage (V_{mxo}):** 250V AC
30–100A
Available amperages (I_{tr})
30, 50, 60, 80, 100

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C-Series Flat Rocker, 1 Pole—Appropriate for DC Main and AC and DC high load circuit protection
Interrupting Capacity (I_{ic}): 5,000A@32V DC/3,500A@240V AC **Maximum Voltage (V_{mxo}):** 32V DC/240V AC
IP Meets Ignition Protection requirements
5–100A
Available amperages (I_{tr})
5, 10, 15, 20, 25, 30, 50, 60, 80, 100

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C-Series Flat Rocker, 2 and 3 Parallel Pole—Appropriate for DC high load circuit protection
Interrupting Capacity (I_{ic}): 5,000A@48V DC **Maximum Voltage (V_{mxo}):** 48V DC
Available amperages (I_{tr})
150, 175, 200, 250, 300
150–300A

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C-Series Flat and Raised Rocker, 2 and 3 Pole—Appropriate for 240V AC Main and AC high load circuit protection
Interrupting Capacity (I_{ic}): 5,000A@240V AC **Maximum Voltage (V_{mxo}):** 240V AC
30–100A
Available amperages (I_{tr})
30, 50, 60, 80, 100

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