From Skipper to Skipper: Lightning Protection for Your Boat

Initially, the plan was to dive straight into the topic of "Device Protection," as promised. However, experience shows that many boat owners often have only a vague understanding of how to effectively protect their vessels from lightning damage. It's a common misconception that grounding the boat alone provides sufficient protection. Therefore, it's essential to take a closer look and ensure proper precautions are in place.

It's unnecessary to explain the dangers of lightning in detail to experienced skippers. Anyone who spends time on the water already has a sense of the raw power of this natural phenomenon. The focus here is less on the theory behind lightning and more on the practical steps you can take to protect your boat effectively.

One important point upfront: There is currently no device or method that can completely prevent a lightning strike – Nikola Tesla knew this all too well. However, with the right protective measures, you can ensure that your boat can survive a direct lightning strike with minimal damage.

There is often a tendency to overestimate the danger because it feels so overwhelming. However, it’s not necessary to turn your boat into a fortress to achieve effective lightning protection. Most of the necessary components are already on board; they just need to be correctly combined and implemented. Our goal is to make lightning protection as clear and practical as possible so that you know exactly what matters.

Lightning Protection System

In our technologically advanced world, many tend to view modern solutions as all-powerful. There is often the belief that you just need the right provider offering a "miracle solution" with a guarantee – and you're safe. But it's not that simple. A look at the practice shows that newly produced boats are generally delivered without lightning protection systems. Why? The answer is pragmatic: Shipyards avoid additional costs that could make their products less competitive, especially since comprehensive lightning protection cannot be guaranteed anyway. Manufacturers also assume that the likelihood of a direct lightning strike is relatively low.

Statistically, the risk of being fatally struck by lightning on a boat is extremely low. In the USA, only two cases were recorded last year. By comparison, the odds of winning the lottery, for example in Germany, are over 600 times higher. However, these numbers should not lead to underestimating the risk. While lightning usually strikes the water near the boat, a strike in close proximity can cause significant damage to the boat's electronics. The likelihood of such damage varies by region, ranging from 1:1000 to 1:10000 – and that’s what this is all about.

As mentioned earlier, lightning cannot be stopped. So, if a lightning strike directly hits your boat, the only option is to minimize the damage through preventive measures. A lightning rod,

combined with proper potential equalization, can help safely direct the energy of the lightning into the water and prevent damage to the boat and its crew.

Details of a Lightning Protection System:

- **Objective of the Lightning Protection System:** The main task is to redirect the energy from the lightning strike to minimize damage to the boat and people.

- **Conductive Path from the Mast to the Water:** The lightning current should be conducted from the mast to the water via a highly conductive path with minimal resistance. Since aluminum and stainless steel are not ideal conductors, copper is the better choice here. The conductor should extend beyond the mast; the exact length depends on the boat's design. Consulting a specialist is recommended.

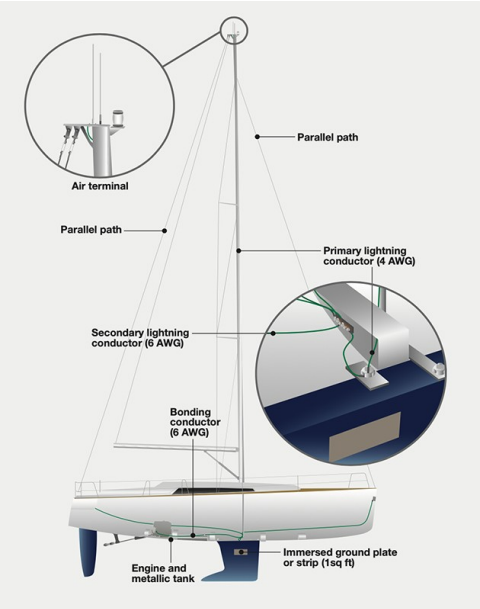


Fig.1 Components of an external and internal lightning protection system. [0]

- **Exit Point into the Water:** The exit point of the lightning rod into the water must be free of paint, filler, or antifouling. It is not enough to simply attach the lightning rod to the keel bolt. If the keel bolt is electrically conductive and anchored in the metal keel, ensure that any coating at the exit point does not add resistance that the lightning current must overcome. To minimize this resistance, it's necessary to attach a metal plate or anodes to the keel, where the lightning rod will be secured. If your boat does not have a metal keel, a sufficiently sized metal plate should be mounted in place of the keel. Here too, the connection between the lightning rod and the grounding plate must also have minimal resistance. It is important to regularly check the conductivity of this junction, especially when the boat is lifted out of the water. The green oxide layer on a copper plate adds resistance and should also be regularly checked. A bronze plate could be a better alternative here. For catamarans, the same principle applies: Each hull should be equipped with a grounding plate or anodes.

- **Potential Equalization:** All metal parts on board, such as the railing, bow and stern pulpit, rudder stock, saildrive, photovoltaic elements, motor, battery negative pole, and steering console, must be connected to a central busbar, which in turn is connected to the lightning road. This ensures that no dangerous voltage differences occur between individual parts. When installing the PE (Protective Earth) conductor, it is important to ensure that the DC currents carried by the PE conductor are blocked. This helps prevent galvanic corrosion on components such as the sail drive, engine parts, and valves, which could otherwise reduce the lifespan and performance of the affected parts.

Fig. 2

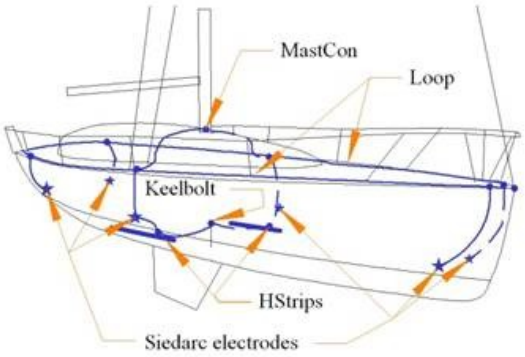
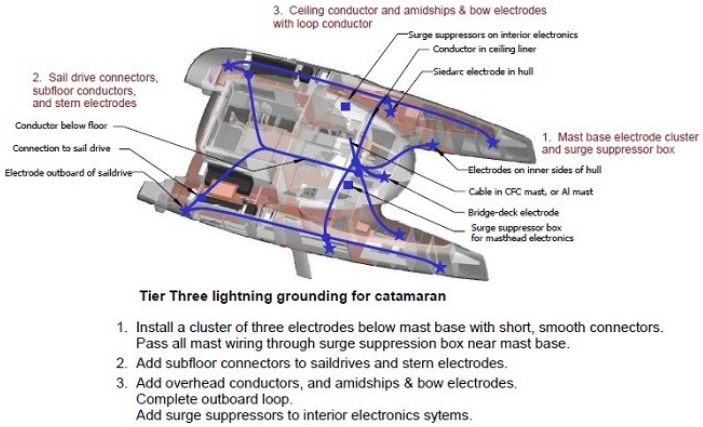


Fig. 3



Typical setup on Monohull (Fig. 2) and Catamaran (Fig. 3) [1]

Resistance and Lightning Protection:

The total resistance of the lightning protection system should be kept as low as possible, ideally close to zero ohms. Higher resistance increases the risk of damage from overvoltage, as the voltage rises proportionally to resistance during a lightning strike. An example illustrates this: If the resistance at the transition point from the lightning rod to the keel bolt is 3 ohms and a lightning current of 100,000 amperes flows, voltages of up to 300,000 volts can arise at this point – enough to cause significant damage to the electronics. [2], [3]
Therefore, it’s crucial to regularly check all connections and ensure that the lightning current is discharged into the water via the shortest and easiest path. A well-installed lightning protection system protects the crew's lives and the structural integrity of the boat.

For the protection of electronic devices, additional measures are necessary, which will be covered in the next section on "Surge Protection." Surge protection for the devices is a useful addition to the lightning protection system, but it is not dependent on it and can be installed separately.

Lightning protection for your boat is about applying practical measures that align with the specific needs of your vessel. While no system can offer 100% protection, the right setup significantly reduces the risk of damage from lightning. By understanding the principles of lightning protection and implementing the best practices, you ensure a safer and more secure environment for both your boat and your crew.

Stay tuned for more insights and detailed guidance in the next section.

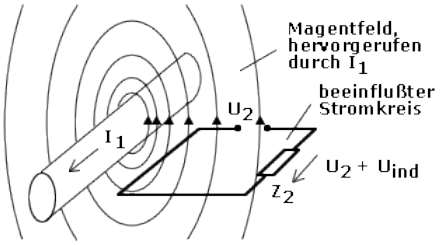
Surge Protection

When it comes to protecting electronic devices on boats, effective surge protection is essential. The best protection is still a Faraday cage, which shields all devices. But in practice, it’s hardly realistic to dismantle all devices before every thunderstorm and pack them into a metal box. Therefore, we need other solutions.

Direct vs. Indirect Lightning Strikes:

Statistically, direct lightning strikes on boats are quite rare. Most damage occurs from indirect lightning strikes, where a bolt hits the water or ground near the boat. This damage is caused by inductive or capacitive coupling, or by the lightning current jumping from the lightning flash to conductive elements on the boat.

Fig. 4



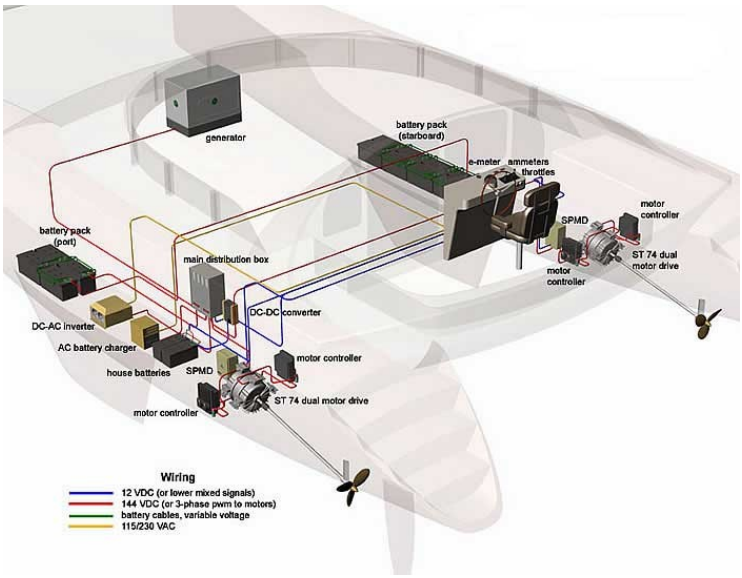
A lightning strike generates a strong magnetic field that builds up in a very short time. This magnetic field infiltrates all nearby electrical circuits, inducing voltage in them. Large conductor loops, which are common in modern boats, are particularly at risk. [4]

Frequency of Thunderstorms and Increasing Damage:

It's often claimed that lightning strikes have become more frequent. In reality, long-term weather records at many locations show no significant increase in thunderstorms.

* Weather History at Gela, Italy [5]

The increase in on-board damage is more attributable to the modern construction of boats and the growing use of electronics. Today, boats are often equipped with BUS systems, which form larger conductor loops and thus provide an ideal target for lightning strikes. In addition, the number of electronic devices on board has increased significantly, further increasing the frequency of damage. In recent years, the power supply on board has also become more complex, especially with the use of large-scale photovoltaic systems. This has led to an increase in both electronics and wiring.



Differences Between Monohull and Multihull Boats:

Multihull boats, like catamarans, are statistically more vulnerable than monohulls. Even at a distance of 400 meters from the lightning flash, the induced voltage in a catamaran can become critical for electronics. At 100 meters, electronic devices are practically always at risk without proper protection. Refer to Table 1.

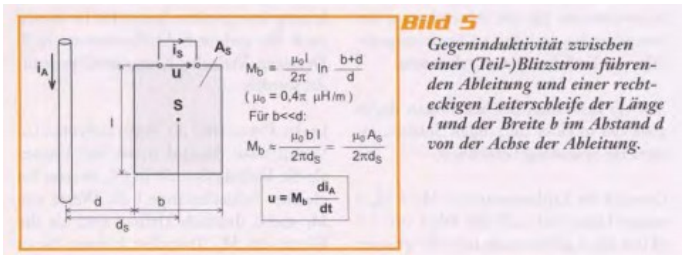


Fig. 5

To determine the values in Table 1, the formula from Fig. 5 was used. For the example calculations, a lightning current of 60 kA and a conductor loop with a length (l) of 5 m were assumed.

Table 1: Effects of indirect lightning strikes on conductor loops of different sizes

Induced Voltage (V) Monohull (Average distance (b) between the wires: 2.5m)	Induced Voltage (V) Multihull (Average distance (b) between the wires: 4.5m)	Distance to Lightning (meter)
149	269	1000
373	671	400
1480	2640	100
13380	22290	10

Damage Mitigation Strategies:

The simplest solution is to completely disconnect all electronic devices on board when a thunderstorm is approaching – emphasis on "disconnect". Simply turning off the devices is usually not enough to protect sensitive electronics from the extreme voltages of a lightning strike.
For one or two devices, disconnecting may still be relatively straightforward, but most modern boats are equipped with a variety of devices and sensors, often installed in hard-to-reach places – from the mast through the bilge to the engine room. Especially during a severe

thunderstorm, when it’s thunder is roaring and rains cats and dogs, you’re unlikely to want to do without this technology. Some of you may have learned firsthand what it's like to suddenly be without orientation or maneuverability at the wrong time and place.

Some professional publications recommend power isolators as a solution to split large BUS conductor loops into smaller segments. This is certainly a good choice when it comes to optimizing power supply and minimizing voltage drop in extensive networks, but it does not provide adequate protection against the effects of a lightning strike. The reason lies in the name: Power isolators only disconnect the power supply, not the data lines.

Effective lightning protection requires that data lines are also interrupted so that data communication remains intact while the physical line connection is separated. The goal is to offer the lightning as little surface area as possible. This means that the relevant physical networks should be kept as small and short as possible. Cable routing and the selection of the right electronic components also play an important role here. [6]

In short: To best protect the electronics on board, you need to ensure that both the power supply and the data lines are optimally secured and segmented into small, manageable sections.

There are good components on the market that allow reliable device isolation while offering some resistance to high voltages. In combination with modern surge protection modules, these components can effectively intercept large amounts of energy, even during a lightning strike, and protect your electronics from damage.

Fig. 6

CAN-BUS-Isolator, bi-directinal Surge Protection [8]

Protection on Drop Cables:

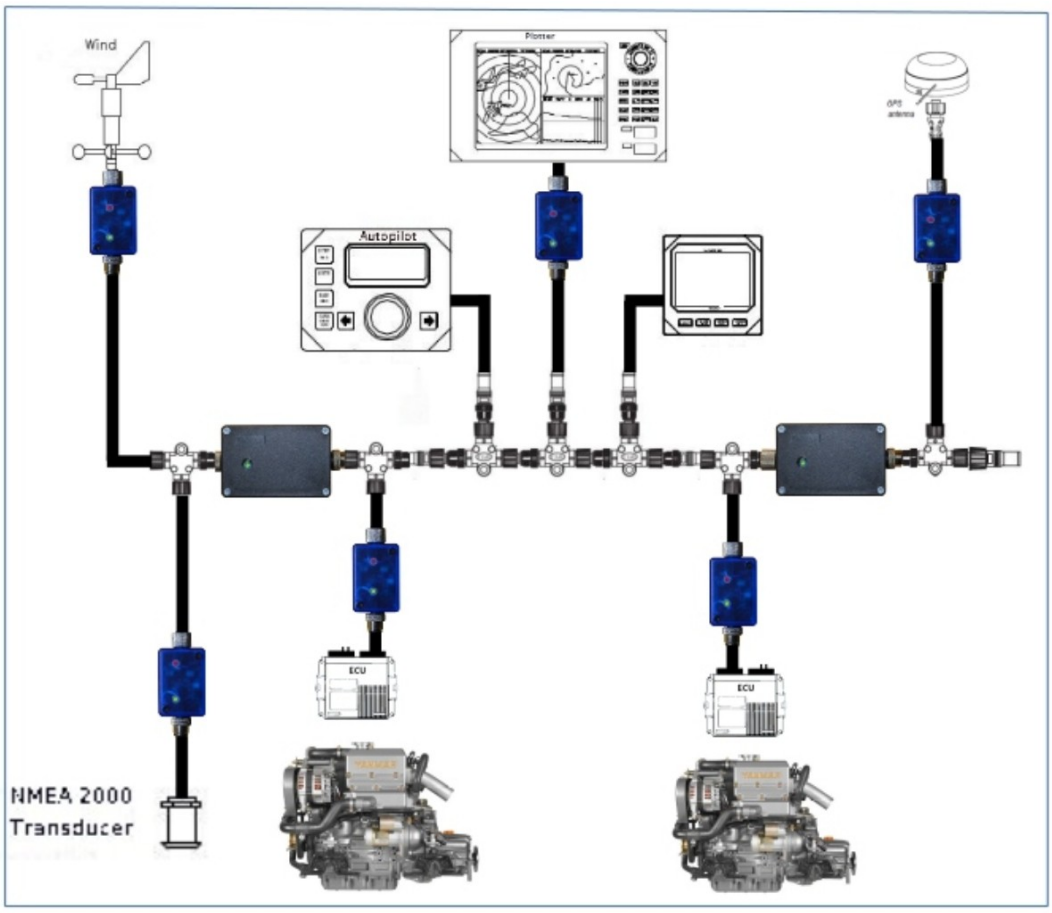
Drop cables run from a BUS to the devices, which can sometimes reach lengths of up to 10 meters. From the perspective of a lightning strike, this cable length already presents a considerable target area where energy can be induced. Therefore, it is especially important to thoroughly secure these cable sections, as the sensitive and valuable devices we want to protect are located at the end of the drop cables. It is therefore advisable to install a surge protector directly at the device at the end of each drop cable if the drop cables are longer than 1 meter.

In summary, surge protection is an essential measure to safeguard the sensitive electronics on board from the effects of a lightning strike. With proper preparation, you can ensure that your devices remain protected even during a thunderstorm.

Fig. 7

CAN-Surge-Intercepter, uni-directional [9]

Fig 8. Example Setup



Addendum: Lightning Protection for Boats – Questions and Answers

After the stormy autumn of 2023, lightning protection has once again become a hot topic among boat owners. Many are asking: How can the crew and the boat be effectively protected from lightning strikes? Here are some frequently asked questions and answers:

1. **What is the best lightning protection system for a boat?** This question is not easy to answer, and sometimes it may seem like there is no perfect solution. The best strategy is often to keep it as simple as possible. In addition to the points already mentioned in the section on lightning protection systems, it can be said: Keep it stupid simple! Complexity only increases the risk of misconfigurations. A straightforward and low-maintenance system is often the better choice for effectively protecting both the crew and the boat.

2. **What do I think of so-called dissipators?** Not much. The science behind them is shaky at best, and dissipators remain in the realm of magic. Neither full nor half-spheres, nor brush-like or broom-like elements can prevent a lightning strike in practice. If you attach a cooking pot or an old hammer to the mast, the result will likely be the same. I have no expert information on these products – they remain in the category of "magic."

3. **Does modern wiring protect devices on its own through the shielding within the cable?** The answer is: YES and NO! The shielding of a cable can indeed reduce the voltage induced by lightning strikes. Depending on how well the shielding is grounded – whether at one end or both – it can reduce the induced voltage by about 30 to 40 percent compared to

unshielded cables. But let’s be realistic: whether it’s 20,000 volts or "just" 12,000 volts – either way, the electronics are likely to be damaged. In both cases, the diodes are likely to fail. Shielding is more intended to minimize unwanted electromagnetic interference from other devices rather than for protection against lightning strikes. Therefore, it is advisable to take additional surge protection measures to safeguard your electronics.

4. **Can I protect my devices during a thunderstorm by turning them off?** Again: YES and NO! For devices connected only to the 12V power supply with no data lines, turning them off can be useful as it disconnects the positive lead from the device, reducing the likelihood of damage. However, devices with additional data lines remain at risk. The sensitive electronics can still be damaged by induced voltage in the data lines, even if the positive lead is disconnected. The best protection is complete disconnection. [7]

   It’s worth noting that, in extreme cases, even with surge protection measures in place, damage to electronics cannot be entirely ruled out. Circuit boards and their tiny components can still be damaged by induced voltages, even when the device is turned off. Unfortunately, it’s often unpredictable – like Schrödinger's cat, you only know if everything survived after the storm has passed.

5. **Why shouldn't you disconnect the ground wire (GND) from the device?** The negative lead in a 12V/24V power network also serves as the grounding conductor. Surge protection devices use GND to dissipate excess energy. Even if your devices are turned off, a significant amount of energy can still be induced into a data cable. The surge protection we’ve developed works even without the positive lead, protecting your devices regardless of their operating state.

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