



Meeting the DO-160 Lightning Protection Standard

DESIGN > DEVELOP > DEPLOY



MEETING THE DO-160 LIGHTNING PROTECTION STANDARD

Design and qualification strategies for lightning-induced transient susceptibility in rugged airborne electronics

Understanding how RTCA DO-160 Sections 22 and 23 address direct and indirect lightning effects—and how system architecture, cabling, I/O protection, and qualification testing work together to protect airborne electronics.

DESIGNING FOR LIGHTNING IN RUGGED AIRBORNE SYSTEMS

Airborne electronics must continue to operate across a wide range of environmental conditions, including the electrical effects of lightning. Externally mounted equipment such as antennas, exterior lights, air-data probes, sensors, and anti-ice equipment may be exposed to direct lightning effects, while internal avionics and embedded computing systems can be affected by transients coupled through cables and wiring.

Protecting the aircraft is a platform-level challenge. The airframe must provide a low-impedance path that carries lightning current through the aircraft structure and back into the atmosphere while minimizing ignition risk, electromagnetic coupling, and damage to mission-critical electronics. The equipment designer must then address the residual currents and voltages that can reach internal systems through conductive paths.

This white paper explains the role of RTCA DO-160 in lightning qualification and reviews practical design strategies for rugged COTS embedded systems, with particular focus on Section 22 lightning-induced transient susceptibility and the relationship to Section 23 direct effects.

MEETING THE DESIGN AND COMPLIANCE CHALLENGE

Program requirements often flow down from the Department of Defense or a prime contractor with specifications for lightning safety and environmental qualification. Those requirements can be difficult to translate into practical hardware design decisions. A single-board computer, for example, is not expected to absorb a direct lightning strike by itself; compliance depends on how the complete aircraft, enclosure, cabling, grounding, and electronics architecture manage the event.

Atrenne works with aerospace and defense system integrators on rugged COTS embedded computing chassis, backplanes, and integrated assemblies. Customers frequently ask how DO-160 Sections 22 and 23 affect equipment design, what protection belongs at the platform level, what can be handled within the enclosure, and how compliance is validated through qualification testing.

KEY TAKEAWAYS

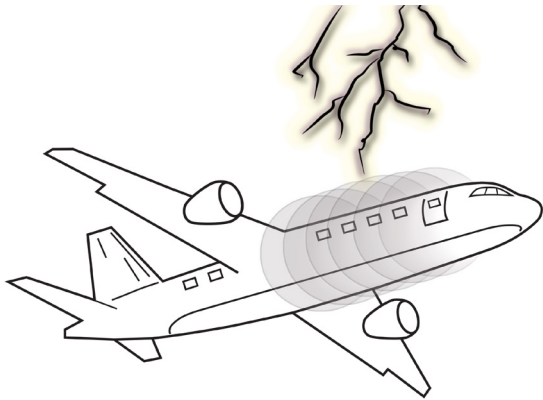
- Lightning protection is most effective when it begins at the aircraft or platform architecture level rather than at the circuit board alone.
- RTCA DO-160 Section 22 addresses lightning-induced transient susceptibility; Section 23 addresses lightning direct effects.
- Shielding, cabling strategy, chassis grounding, I/O protection, and qualification testing must work together as a system.
- For COTS embedded systems, application-specific protection can often be concentrated in the I/O front panel or associated I/O circuitry, allowing standard payload modules to remain unchanged.

LIGHTNING EFFECTS: DIRECT AND INDIRECT

Direct Effects

Aircraft are divided into zones with different levels of lightning exposure. Some zones are well protected from high-voltage transients, while others must tolerate the effects of a direct strike. The platform designer must understand how the airframe, cabling, and other conductive elements route lightning current and how energy can couple into equipment throughout the aircraft.

Metal airframes provide a relatively low-impedance conductive path, helping the aircraft structure act as a Faraday cage. Composite materials reduce weight but typically have higher electrical impedance than metal, increasing the importance of careful bonding, shielding, and cable routing. As impedance increases, voltage and current are more likely to couple onto internal wiring and into avionics or mission electronics.



Conductive metal skin keeps electricity from the interior of the plane

Lightning-Induced Transients and EMF Interference

Equipment inside the aircraft may also be electrically connected to externally mounted sensors or antennas. Optical cabling can eliminate electromagnetic coupling along the data path. Where optical links are not practical, properly shielded cabling can help confine current to the cable shield and chassis ground, reducing the energy that reaches sensitive electronics.

Even when the direct lightning current is safely conducted through the airframe, the associated electromagnetic field can induce transient voltages and currents on wiring. These indirect effects are commonly referred to as lightning-induced transients.

A properly shielded cable places insulation between the center conductor and the outer shield, providing a controlled path for induced current and reducing the electromagnetic field seen by the signal conductors. Unshielded cable, while sometimes used to reduce weight or complexity, is more susceptible to induced transients and can expose sensitive electronics to severe voltage and current spikes.

An induced pulse on an unshielded cable can be significantly more severe than a typical human-body electrostatic-discharge event. Designers therefore use platform-level shielding first, then add circuit-level clamping or current-diversion strategies where needed. Circuit protection should be viewed as a final layer of defense rather than a substitute for sound aircraft-level architecture.

QUALIFICATION TESTING

Lightning-induced noise typically enters a processing subsystem through external I/O interfaces. Qualification testing therefore reproduces representative transients at those interfaces and verifies that the equipment can tolerate the required exposure without damage or unacceptable disruption.

One common method is pin injection, in which a defined transient is applied directly to an external I/O pin with a return to case ground. Cable-bundle testing applies the transient through cable induction or ground injection and evaluates the response of individual conductors or a cable bundle as a whole.

RTCA AND THE DO-160 STANDARD

RTCA is a nonprofit aviation standards organization that develops consensus-based guidance and recommendations for aviation systems and airborne equipment. Its documents are widely used by government agencies, aircraft manufacturers, defense contractors, system integrators, and equipment suppliers as the basis for qualification requirements.

DO-160, Environmental Conditions and Test Procedures for Airborne Equipment, defines environmental test methods used to evaluate airborne equipment under conditions representative of flight. In defense electronics, DO-160 commonly appears in program requirements and qualification plans for airborne platforms.

Environmental Categories Addressed by DO-160

- Temperature and altitude
- Temperature variation
- Humidity
- Vibration
- Explosive atmosphere
- Waterproofness
- Fluids susceptibility
- Sand and dust
- Fungus resistance
- Salt fog
- Power input
- Voltage spike
- Audio-frequency conducted susceptibility - power inputs
- Induced signal susceptibility
- Radio-frequency susceptibility
- Emission of radio-frequency energy
- Lightning-induced transient susceptibility
- Lightning direct effects
- Icing
- Electrostatic discharge (ESD)
- Fire and flammability
- Environmental test identification

LIGHTNING-INDUCED TRANSIENT SUSCEPTIBILITY

RTCA/DO-160 Section 22

A direct lightning strike can create indirect voltage and current transients through magnetic- and electric-field coupling. RTCA DO-160 Section 22 defines test methodologies for evaluating equipment susceptibility to these lightning-induced effects. Section 23 separately addresses lightning direct effects.

Section 22 allows equipment to be tested to an exposure level appropriate to the expected installation environment. The aircraft is divided into zones with different electromagnetic severity profiles. Well-protected environments have the least stringent requirements; equipment installed in severe electromagnetic environments requires greater reliance on platform-level shielding and architecture.

For VPX-based C4ISR equipment, platform shielding and cable management become increasingly important at the more severe exposure levels. I/O-board and front-panel mitigation can be effective for lower and moderate levels, but the physical size and energy-handling capability of protection components can limit how much of the requirement can be addressed inside the enclosure alone.

Effect	Definition	Qualification testing
Lightning direct effects	A large surge of charge resulting from a direct lightning strike to equipment or structure exposed on the aircraft.	DO-160 Section 23
Lightning indirect effects	Transient current and voltage introduced into wiring or electronics through electromagnetic coupling from lightning current flowing through the aircraft structure.	DO-160 Section 22

Table 1. Qualification guidance for lightning effects

Level	Description	Primary focus of mitigation
1	Well-protected environment.	I/O panel and local circuitry
2	Partially protected environment	I/O panel and local circuitry
3	Moderately protected environment	I/O panel and local circuitry
4 and 5	Severe electromagnetic environment	Platform design, shielding, bonding, and cabling

Table 2. Environmental severity levels and design focus

Mitigating lightning effects on sensitive airborne electronics requires a top-down design approach. Aircraft structure, bonding, shielding, cable routing, connector selection, chassis grounding, and interface protection all contribute to the final level of resilience.

LIGHTNING-INDUCED TRANSIENT SUSCEPTIBILITY

RTCA/DO-160 Section 22

DO-160 ELECTRONICS TESTING DETAILS

Section 22 uses two basic categories of tests:

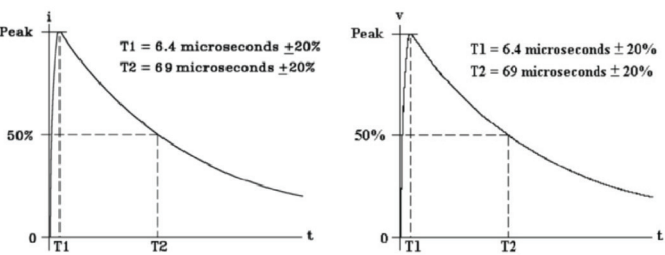
- Pin injection tests - a simulated transient is applied directly to the pins of the external I/O interface, usually between each pin and case ground. The purpose is to verify that the equipment under test tolerates the required transient without damage or unacceptable interruption.
- Cable-bundle tests - a transient is applied through cable induction or ground injection. The pulse may be applied to individual conductors or to a cable bundle.

DO-160 defines canonical transient waveforms and test levels that establish the required open-circuit voltage and short-circuit current. The table below summarizes the generator settings shown in the source document for pin-injection qualification.

Level	WAVEFORM					
	3/3 Voc (V)	3/3 Isc (A)	4/1 Voc (V)	4/1 Isc (A)	5A/5A Voc (V)	5A/5A Isc (A)
1	100	4	50	10	50	50
2	250	10	125	25	125	125
3	600	24	300	60	300	300
4	1500	60	750	150	750	750
5	3200	128	1600	320	1600	1600

Table 3. Waveform generator setting levels for pin injection.
Voc = peak open-circuit voltage; Isc = peak short-circuit current.

For example, a Level 3 test using the 4/1 waveform combination applies a 300 V voltage transient following **Waveform 4** and a 60 A current transient following **Waveform 1**. The standard includes additional waveform shapes and multi-stroke pulses to represent different induced-lightning conditions.



Atrenne works with aerospace and defense system integrators to develop rugged electronic packaging, chassis, backplanes, and integrated assemblies for demanding airborne applications. Engage with our team to discuss how platform architecture, shielding, I/O protection, grounding, and chassis design can support your DO-160 Section 22 qualification strategy while preserving the benefits of COTS embedded computing.

DESIGN CONSIDERATIONS

ESD-Protected Components

Designing for DO-160 Section 22 qualification requires a review of each external interface and a protection strategy matched to that interface. ESD protection built into a component is a useful starting point, but it should not be assumed to provide adequate lightning-transient protection. DO-160 waveforms can present substantially different energy, voltage, current, and time profiles than a human-body ESD event.

Protection circuitry can be added to the front-panel I/O board so that the incoming transient is clamped or diverted to a level that the downstream component can tolerate. This approach makes the enclosure and I/O architecture part of the compliance strategy while preserving the use of standard COTS payload electronics.

I/O Interfaces

Lightning protection is generally easier to implement on lower-speed signals such as MIL-STD-1553, RS-422/232, GPIO, and analog interfaces because those signals can tolerate more of the shunt capacitance introduced by transient-suppression circuitry.

High-speed serial interfaces such as Gigabit Ethernet, SATA, and USB are more difficult to protect at higher exposure levels without degrading signal integrity. In these cases, system designers may concentrate high-speed I/O on common connectors and rely on application-rated shielded cabling, careful grounding, and platform-level mitigation.

Protection components

Lightning-protection circuits may use Zener diodes, transient-voltage suppressors, thyristors, and related devices to clamp voltage or divert transient current to chassis ground. A thyristor, for example, can remain effectively open during normal low-voltage operation and switch into conduction when the input exceeds a defined threshold, routing a short-duration surge away from sensitive downstream circuitry.



Thyristor
protection
concept

The front I/O panel and its associated circuit-card assembly are therefore key elements in many lightning-mitigation designs. Locating protection circuitry on a separate I/O card allows the protection to be tailored to each application while retaining standard VPX or other COTS payload modules. If a dedicated I/O card is not available, protection may be incorporated on the backplane where space permits. Redesigning payload modules with application-specific mitigation is typically a last resort because board area on COTS modules is limited and valuable.

SUMMARY

Mitigating lightning effects on sensitive airborne electronics requires a top-down design approach. Aircraft structure, bonding, shielding, cable routing, connector selection, chassis grounding, and interface protection all contribute to the final level of resilience.

RTCA DO-160 provides the qualification framework for validating that equipment can tolerate its specified environment. Section 22 focuses on lightning-induced transient susceptibility, while Section 23 addresses direct lightning effects. For rugged COTS embedded systems, application-specific I/O protection can often be integrated at the enclosure boundary so that standard payload electronics can be retained while meeting program-level qualification requirements.

ENGAGE WITH ATRENNE TO DISCUSS DO-160 QUALIFICATION

Atrenne works with aerospace and defense system integrators to develop rugged electronic packaging, chassis, backplanes, and integrated assemblies for demanding airborne applications. Engage with our team to discuss how platform architecture, shielding, I/O protection, grounding, and chassis design can support your DO-160 Section 22 qualification strategy while preserving the benefits of COTS embedded computing.

ABOUT ATRENNE

For more than 50 years, Atrenne Computing Solutions has been designing, developing, and deploying rugged electronic packaging, chassis, backplanes, and integrated assemblies for mission-critical applications.

We provide fully tested, reliable electromechanical solutions with a design-to-build model and custom engineering capabilities that support programs from concept through production and lifecycle management. Atrenne embedded computing platforms are deployed across aerospace, defense, and other demanding applications worldwide.

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