



AEROSPACE INFORMATION REPORT

AIR1810™**REV. C**

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Superseding AIR1810B

(R) Design, Development, and Test Criteria -
Solid State Proximity Switches/Systems for Landing Gear Applications

RATIONALE

AIR1810C has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

This document examines the most important considerations relative to the use of proximity sensing systems for applications on aircraft landing gear. In general, the recommendations included are applicable to other demanding aircraft sensor installations where the environment is equally severe.

1.1 Purpose:

The purpose of this SAE Aerospace Information Report (AIR) is to suggest specification, application, performance, and validation criteria for solid-state proximity sensing systems used for environmentally severe applications on aircraft landing gear.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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<https://www.sae.org/standards/content/AIR1810C>

Documents

Document Sharing Hub

2.1 Military Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-C-85049	Connector Accessories, Electrical, Backshell, Environmental, Cable Sealing, Straight
MIL-I-16923	Insulating Compound, Electrical, Embedding, Epoxy
MIL-PRF-23586	Sealing Compound (With Accelerator), Silicone Rubber, Electrical
MIL-W-22759	Wire, Electric, Fluoropolymer-Insulated, FEP-PVF2, Lightweight, Silver-Coated, High Strength Copper Alloy Conductor, 600-Volt
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-810F	Environmental Engineering Considerations and Laboratory Tests

2.2 RTCA, Inc. Publications:

Available from RTCA, Inc., 1140 Connecticut Avenue, NW, Suite 1020, Washington, DC 20036-4001.

RTCA DO-160D Environmental Conditions and Test Procedures for Airborne Equipment

3. DISCUSSION:

3.1 Integral Electronics Proximity Switch Characteristics and Performance:

Non-contacting proximity switches have been used on some aircraft as landing gear control and indication limit switches since 1965. There are two kinds of proximity sensing systems in common use: proximity switches that have the switching electronics built into the sensing head and operate on the principle of eddy current losses, and proximity sensors that use variable reluctance and are connected to remote switching electronics contained in a separate electronics module. Proximity sensors produce an output that is a function of the distance between the sensor and its target, and this characteristic can be used to provide the maintenance technician with help during rigging. Proximity switches, on the other hand, only provide a bistable output – ‘target near’ or ‘target far.’

Integral Electronics Proximity Switch Characteristics and Performance:

The following briefly describes the features and characteristics of the “one-piece” proximity switch.

- a. Installation: No separate electronics module is required.
- b. Reliability: Experience has demonstrated a Mean Time Between Failures (MTBF) of 5,000 to 50,000 hours for each switch, depending on exposure and application.
- c. Maintainability: Integral proximity switches are generally not repairable.

3.1 (Continued):

- d. Sensing Range: From 0.050 to 0.5 inch as a function of effective sensor area or sensor diameter.
- e. Target: Any conductive material: however, the actuation point varies with different materials. Ferromagnetic steel generally provides the maximum actuation range and should be utilized whenever possible.
- f. Temperature Range: From -55 to 71 °C is normal. The upper limits can be extended to 125 °C if the thermal interface is specified and controlled and adequately rated electrical parts are used.
- g. EMI Capability: No practical limitations except radiated susceptibility. Normal designs should be capable of operation in 20 volt per meter fields. Special designs that can operate in fields in excess of 300 volts per meter from 5 KHz to 4 GHz are presently in service. Aircraft HF, VHF and UHF transmitter bands should be tested.
- h. Shock: Current devices are capable of survival at up to 50 g shock levels. This limitation is dictated by electronic die attachment capability.
- i. Vibration: It is of the greatest importance that the mounting provisions account for the relative motion between the switch and target during exposure to vibration. The mounting hardware must be stiff enough to limit the change in the sensing gap to not more than 15% of the nominal gap when it is reacting the forces imposed by the switch during acceleration. The target must also be robustly mounted. Each installation should be designed to limit motion in both the head-on and slide-by directions during deflection of the structure to prevent false indications. Depending upon mechanical mounting features and possible resonances of individual installations, normal designs are capable of withstanding 25 to 75 g RMS equivalent vibration. Special designs are limited only by the capability of the microcircuits and other components used in the design.
- j. Moisture/SWAMP Environment: The SWAMP is defined as a “severe wind and moisture problem” area. Experience has shown that moisture ingestion is the principal cause of premature failure of integral electronics proximity switches. Sealing integrity is severely tested by the rapid temperature and pressure changes associated with the SWAMP landing gear environment. It is strongly suggested that development and qualification test programs include the test parameters outlined in Section 5. Production testing requirements should also consider the inclusion of a cycled high stress burn-in period (“Shake and Bake”) to improve reliability by weeding out “infant mortality” failures.

3.2 Separate Electronics Proximity System Characteristics and Performance:

Included here are the characteristics of the typical “two-piece” proximity switch system.

- a. Installation: Electronics modules, usually packaged together in a standardized Air Transport Radio (ATR) proximity electronics enclosure, are required to be located in an environmentally controlled aircraft area. Any required logic, output drivers, and Built-In-Test (BIT) circuitry are usually included in the same enclosure. Point to point wiring, within the enclosure, is preferred for ease of maintenance and modification if space constraints allow.
- b. Reliability: This type of system has demonstrated a field MTBF of 180,000 to 300,000 hours for each switch channel (one sensor together with its electronics module). The reason for the large improvement in reliability, over the one-piece switch, is that the electronics module is housed in a controlled aircraft environment and the sensor is a low impedance device that is inherently less sensitive to moisture ingestion.
- c. Maintainability: Electronics modules are repairable and replaceable without disturbing the sensor installation/rigging. Sensors are non-repairable, but can be replaced without adjustment of the electronic module.
- d. Temperature Range:
 - 1. Sensor: Normal -55 to 85 °C or -65 to +100 °C. The range may, with special design effort be extended to -200 to +450 °C.
 - 2. Electronic Module: -40 to +71 °C.
- e. Sensing Range: Similar to integral electronics unit.
- f. Target: Must be a ferromagnetic material such as 4130, 4340 or 17-4PH steel. For increased switching range and sensitivity, specialty high permeability alloys may be used. This system has the inherent capability of “seeing through” non-magnetic metals such as 300 series stainless steel and titanium.
- g. EMI Capability: The same as integral electronic switches except that care must be taken to ensure that radiated emissions requirements are met on the wires connecting the sensor to the electronics module. Sensor wiring is usually a twisted pair or triple for improved EMI rejection.

3.2 (Continued):

h. Shock and Vibration:

1. Sensor/Target: As with proximity switches, it is of great importance that the mounting provisions account for the relative motion between the sensor and target during exposure to vibration. The mounting hardware must be stiff enough to limit the change in the sensing gap to not more than 15% of the nominal gap when its reacting the forces imposed by the switch during acceleration. The target must also be robustly mounted. Each installation should be designed to limit motion in both the head-on and slide-by directions during deflection of the structure so that false indications are prevented. No practical limitations exist except with mounting features that are unique to individual designs. Switching repeatability is enhanced by rigid, well-designed installations.

2. Electronics Module: The normal electronics bay environment should not be exceeded without special care.

- #### i. Moisture/SWAMP Environment:
- The sensor in the separate electronics system is a low impedance device that is not inherently sensitive to moisture ingestion. However, moisture penetration can cause long-term deleterious effects resulting from corrosion and freeze-break failure.

4. SUGGESTED PRACTICES FOR DESIGN, DEVELOPMENT AND APPLICATION:

4.1 Materials:

- a. All exposed parts must be of corrosion resistant or protected to resist corrosion and structurally capable of surviving in the wheel well environment. Non-metallic materials should be resistant to the effects of ozone and ultra-violet radiation.
- b. Abutting dissimilar metals should not be used when exposed to wheel well conditions without special precautions.
- c. All potting and encapsulation compounds that are exposed to wheel well conditions must be unaffected by moisture. Suggested criteria are those of MIL-I-16923 for epoxies, and MIL-PRF-23586 for silicones. Potting voids should be eliminated since they tend to collect contaminants and moisture. Hermetic techniques that eliminate exposed potting and encapsulation materials are preferred.
- d. In order to maximize reliability, the order of preference in the construction of solid state electronic circuitry is as follows (the most preferred construction listed first and the least preferred last).
 1. Monolithic microelectronic integrated circuits;
 2. Thin film, thick film, or hybrid microcircuit devices
 3. Discrete parts.
- e. External components and surfaces should not be susceptible to, or damaged by aircraft fuel, hydraulic fluids, disinfectants, de-icers or cleaning agents.

4.2 Construction:

- a. Mounting: The sensor mounting means should prevent all relative motion between the switch and the structure to which it is attached. Proximity switches or sensors are not sensitive to mounting attitude. If units are to be installed within one inch of each other, care should be taken to ensure that the effects of one on the other are understood and acceptable. In addition, the effects of surrounding metal structure must be considered.
- b. Electrical Termination: Most switches or sensors include twisted “pigtail” leads or shielded cables. The aircraft manufacturer usually specifies the type and length of wire or cable. However, experience has shown that sensor wiring that meets the following guidelines, when located in the wheel well environment, will provide satisfactory service:
 1. Size:
 - (a) 20 gauge minimum for twisted 2 or 3-wire cable.
 - (b) 22 gauge minimum for twisted, shielded and jacketed multi-wire cable.
 2. Wire: High-strength copper alloy with silver plating is generally preferred. Wire insulation systems that use flexible, homogenous modified Teflon of medium weight, are also generally preferred over lightweight multi-wall, stiff, springy constructions. MIL-W-22759 is a reasonable, basic wire specification. For installations where the sensor harness has to be very flexible (e.g., routing the sensor wire in conduits that fold with a side brace mechanism or that are routed over the torque link apex), a wound (wrapped) wire insulation provides much better flexibility and endurance than extruded insulation systems.
- c. “Wind-whip” and flexure during gear operation have created long term reliability problems with stiff, springy wire and cable in landing gear applications.
- d. The use of integral connectors on proximity sensors or switches in the wheel well may appear to offer maintainability advantages. However, a number of factors must be considered.
 1. A connector can add cost and weight, and increase the space required to mount a sensor. In addition, a connector adds series wire connections and increases the probability of electrical failure owing to wire-to-wire and wire-to-ground leakage within the connector assembly, which is greatly exacerbated by the wheel well environment. The service histories on some aircraft landing gear installations show that cable-related failures account for a high percentage of switch problems. The use of connectors for sensors on landing gear installations should be avoided. In the wheel wells, connectors should be only used where they are not directly exposed to spray or driving rain, and they should be oriented horizontally to avoid the collection of moisture and contamination in open cavities of the connector.
 2. It is recommended that the use of integral connectors be decided according to the details of the individual installation. If the associated wiring can be adequately protected from corrosion, wind whip, and mechanical damage, the use of a connector is probably not justified.