## *Military- Vs. Commercial-Grade Resistors: Reliability, Performance And Cost Tradeoffs*

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Military-spec resistors provide an essential function in high reliability and critical circuit applications. However, unless you are dealing with such applications regularly, understanding what military-spec (military-grade) resistors offer compared to commercial resistors can be challenging. There are many aspects of military-spec resistors that are unclear or unknown to many customers. For example, a key distinction among military-spec resistors is whether or not they offer *established reliability*.

When considering the use of military-spec resistors, it's important for designers to understand what the established reliability designation (or lack thereof) means in terms of resistor reliability as compared to commercial-grade resistors as well as other distinctions. Further, some of the automotive-grade resistor options that have been recently developed offer some of the same benefits as certain military-spec resistors. So, it's important for engineers to understand how the reliability of automotive-grade devices relates to military-grade resistors with and without established reliability.

This article explains in broad terms how military specifications address reliability in the manufacturing, testing, inspection and processing of resistors, and how these aspects compare with those used to produce commercial- and automotive-grade resistors. The distinctions between mil-spec resistors with established reliability versus those without are highlighted. To understand the full picture, the first step is to identify the military specifications pertaining to the most-used resistors.

### *Military Specifications*

The figure below shows the wide range of military specifications covering film resistors, wirewound resistors, axial leaded, surface mount, chassis mount, network, and variable resistors. Due to the wide range of resistor types and mounting, the testing required for each spec will vary. Many resistor product groups have military specs with established reliability requirements, but some do not have established reliability.

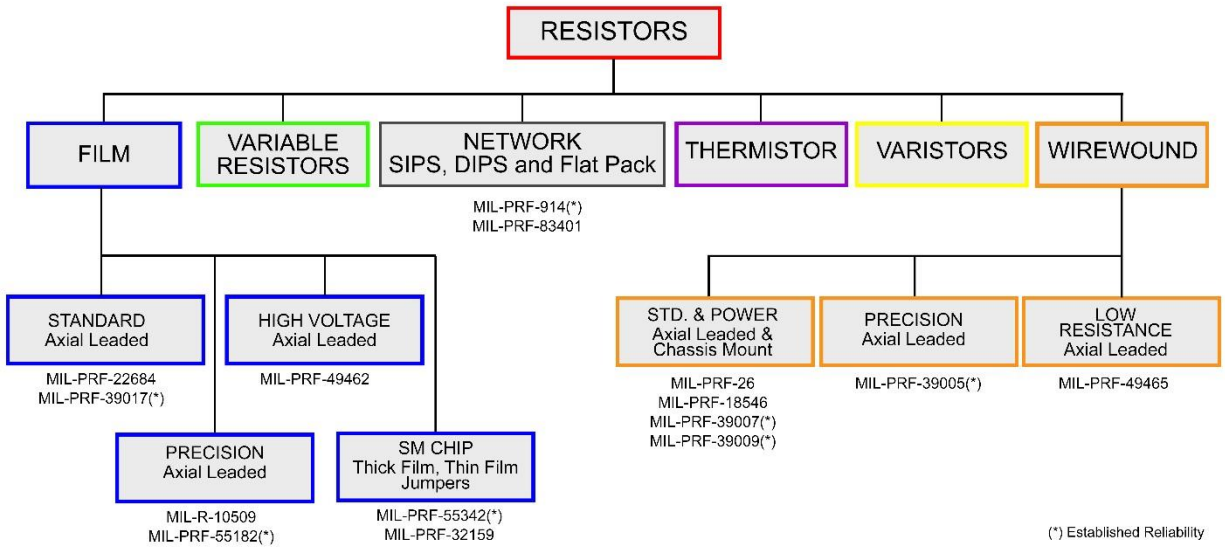


*Figure. Overview of military specifications pertaining to fixed resistors.*

Those military specs with established reliability requirements generally require materials to be qualified to a military controlled baseline and cannot be modified or substituted unless pre-approved. Non-established reliability military parts generally use the same or similar materials but do not require baseline conformance. Depending on the spec, manufacturers may be allowed minor modifications or substitutions if they produce a final product which conforms to the required military standard.

Military specifications with established reliability require full material traceability where non-established reliability and commercial parts do not. Commercial resistors generally allow substitutions and modifications to processes or materials if the final product conforms to the commercial data sheet.

As a result of more stringent performance and reliability requirements, military resistors will often have a lower power rating for a given body size or footprint. Lower power ratings allow any resistor to perform better, with a smaller expected change in resistance, over a longer time period, than the same resistor with a higher power rating.

Military resistors, especially those with established reliability and additional group testing (more on this later), are also understandably more expensive. There is a cost associated with specialized materials and for the testing necessary to confirm compliance to the military standard.

Commercial applications typically have different priorities. Most commercial designs focus on lower cost, conserving board space for additional functions and minimizing the size of the circuit design. For these applications, military-spec resistors are not the best choice.

## *Testing And Inspection*

The requirements for quality assurance and reliability depend on the resistor type and quality level. There may be group testing requirements performed on a sample basis, depending on the military spec. Group testing involves a broad range of environmental, electrical, and, in some cases, destructive tests to ensure product capability.

Table 1 shows some typical group A, B, and C tests for chip resistors, standard film and precision film axial-leaded resistors, and wirewounds. This is not a comprehensive list of the group tests, but an example of common testing that is required. Some tests are not required for some group tests and some are required for multiple groups.

Table 1. Typical group testing requirements for resistors.

**Typical Group Resistor Inspection / Test Requirements For Military Resistors**

| Inspection / Test | Chip Resistor | Standard Axial Film | Precision Axial Film | Wirewound |
|---|---|---|---|---|
| Visual Examination | A | A , B | A , B | A , B |
| Resistance | A | A | A | A |
| Thermal Shock | A , C | C | A | |
| Solderability | | A | A | A |
| Dielectric Withstand Voltage | | | | A |
| Resistance to Solvents | A | B | B | B |
| Noise | | | A | |
| Marking Legibility | A | | | A |
| Power Conditioning | | A | | |
| Destructive Physical Analysis (DPA) | | | A | A |
| Short Time Overload | B | B | | A , C |
| Life | C | C | C | C |
| Moisture Resistance | C | C | C | C |
| TCR | B | B | B | |
| Mechanical Shock | C | C | C | C |
| Vibration | | C | C | C |
| Low Temp Storage | | C | C | C |
| Low Temp Exposure | | C | | |
| High Temp Exposure | C | C | C | C |

LEGEND:
A = GROUP A TEST REQUIREMENTS
B = GROUP B TEST REQUIREMENTS
C = GROUP C TEST REQUIREMENTS

These tests can be costly and time consuming and, in some cases, must be performed on a single part at a time. For commercial applications where cost and time to market are critical, this type of testing and inspection is often unrealistic, and the costs outweigh the benefits. For military applications, aircraft and avionics, missile systems, radar, space, and critical medical applications, however, the ability to verify and thereby guarantee performance is essential to the ultimate success of the end device.

Commercial resistor testing and inspection procedures vary with mounting method (such as surface mount or axial leaded) and technology (such as film or wirewound). For example, thick film resistors are visually inspected continuously on a sample basis during each of the print, dry and fire processes for the thick film materials. This is done to verify alignment, registration, and resolution of the printed layers. However, 100% inspection is not done, and the materials will not be compared to a military established and accepted baseline. But materials must pass an incoming inspection and verification depending on the material and all materials must conform to the applicable material data sheet.

Each process may have its own inspection requirements in terms of frequency and pass/fail criteria. Many commercial parts will have a more comprehensive quality inspection during the manufacturing process to ensure that the production lot is proceeding with the proper quality and yield output. Final QC testing also typically includes visual inspection along with resistance check.

Resistors are tested for resistance again just before final packaging; this resistance check typically has a guard band that is narrower than the required tolerance. For instance, resistors with an absolute ±5% tolerance, may be tested at final test at ± 4.9% to ensure the part when received by the customer is indeed within the 5% order tolerance.

### *Reliability*

Reliability is one area where the additional testing, inspection, and processing from a military-qualified resistor can provide a substantial benefit. The determination of reliability is typically based on 10,000 hours of load life testing in addition to other environmental and electrical tests depending on mounting type and technology. Further, military-spec resistors with established reliability maintain their quality level through continuously testing thousands of parts in a military approved test lab.

The ultimate failure rate obtained by a production lot is based on the results of this rigorous testing and the specific data results for any lot can be provided to the end customer to ensure compliance. For military-spec resistors that do not require established reliability, there is typically only periodic testing from components taken at prescribed intervals and tested for compliance with specific environmental and electrical parameters. Load life testing is typically only done for 1000 hours. Test data summaries for each production lot may be provided to the end customer as requested and are retained for an extended period.

For commercial resistors, parts are typically tested less frequently to ensure compliance with the data sheet. Depending on the product, periodic test results may or may not be available. Normally each product lot maintains a group of keep samples from the production lot to help with possible failure analysis that may be required in the future. Among the regular periodic tests, which again depend on the mounting type and technology, load life is typically done for 1000 hours.

It is easier for the manufacturer to maintain production lead times and manufacturing capacity because they can use equivalent materials if those materials are tested and shown to produce product that fully complies with all electrical, dimensional, and performance requirements set forth in the data sheet. Commercial resistors may also be able to customize the part performance to a customer requirement, where military-spec resistors have rigidly defined performance and characteristics that are not allowed to be adjusted under any circumstances.

Failure rates for commercial resistors are typically based on failures experienced versus total number of components shipped. Some typical failure rates for commercial resistors are shown in Table 2 along with the designated failure rates for military established-reliability resistors.

For applications that do not require military-level established reliability, the benefits of military-spec resistors compared to commercial equivalents vary from product to product. The benefits for non-established reliability military components compared to commercial resistors are minimal for some types of resistor products. Outgoing DPPM (defective parts per million) levels of less than 10 ppm for thick film and less than 2 ppm for thin film provide excellent long-term reliability in a commercial product. In addition, the flexibility and cost of commercial resistors may enable faster design, prototype, and production cycles to get a product to market in the shortest time.

Table. 2 Failure rates of military-grade and commercial-grade resistors.

| Failure Rate Level Designation | Failure Rate (% / 1000 hours) |
|---|---|
| C | Non-established Rel. |
| M | 1 |
| P | 0.1 |
| R, U | 0.01 |
| S, V | 0.001 |
| T | Space Level |
| **Commercial Product** | **Typical Failure Rate (DPPM)** |
| Thick film SMD | <10 ppm |
| Thin film SMD | <2 ppm |

> Military failure rate designation based on specific hours of testing in qualified lab.

> Commercial product failure rate based on failures and units in the field, 60% confidence. Rates vary with size and tolerance.

## *Automotive-Grade Resistors*

In recent years, another level of reliability for resistors has emerged. Automotive-grade resistors provide an excellent alternative for improved reliability and consistency compared to commercial resistors, without the rigorous structure of established-reliability-level military components.

Automotive-grade resistors typically have a more restrictive material retention rule than commercial equivalents; materials will not be used if they exceed a preset date restriction. In addition, automotive-grade resistors are manufactured by certified operators who have passed performance testing. They are manufactured on separate manufacturing lines with tighter controls and more rigorous maintenance. Finally, automotive-grade resistors are subject to 100% automated optical inspection (AOI).

The combination of these material and process improvements typically allows the automotive-grade components to achieve calculated expected failure rates that are significantly better than commercial equivalents. In some cases, manufacturers may agree to a guaranteed outgoing ppm level based on requirements from the customer.

## *Summary*

The reliability, consistency, and traceability of military established-reliability resistors cannot be overstated. For critical military, medical, aerospace, and aircraft applications, this level of guaranteed performance is irreplaceable.

However, commercial resistors have inspection, testing, and reliability levels that may rival that of non-established-reliability military resistors. Commercial resistors also offer the shortest lead times, best cost, and in some cases design flexibility to match customer needs. Beyond that, automotive-grade resistors provide an improved level of material and process constancy, for improved reliability compared to commercial resistors at a cost that is significantly less than military-level resistors.

**About the Author**

*Kory Schroeder currently serves as the director of Marketing and Engineering at Stackpole Electronics. His experience includes applications engineering for film capacitors with American Shizuki and product management, applications engineering, and field applications engineering with Vishay Intertechnology in their resistor division. Kory graduated from the University of Nebraska—Lincoln with a bachelor's degree in electrical engineering.*

For further reading on power supply-related safety and compliance issues, see How2Power's special section on Power Supply Safety and Compliance.