本文说明为美军工作的承包商如何在没有军用零件时，将商用零件用于军事应用。扩大筛选，又称使用周期筛选，可帮助确保民用零件具有军用所要求的长期可靠性。这种方法称为加坚固技术化。军用品承包商对这些零件进行试验，使其暴露在盐雾、雨、振动、极限温度、极限湿度、爆炸环境、低压和其它严酷环境下。

COTS Ruggedization Simplified

Linda Britt

Yes, the military often buys the same parts from the same supplier you do. But how best to ensure that these civilian parts meet the military's requirements?

The use of commercial parts in military systems is now commonplace. In fact, the use of military parts is no longer a viable option, as the availability of such rigorously specified, tested and guaranteed parts wanes. Many of the manufacturers of the military versions, i.e., “mil parts,” either no longer exist or are no longer interested in such cost expenditures for so little return. The military customer represents less than 1% of the semiconductor market today.

Making the best use of “commercial-off-the-shelf” (COTS) parts in a military environment becomes the challenge. The use of COTS parts has been approved by the military for more than a decade, but the systems into which they are embedded must still operate reliably in harsh environments. Clearly a method must be found for upgrading the commercial nature of the part, or determining if the so-labeled “commercial” part is actually capable of better performance than the characteristics recorded on a catalogued datasheet.


FIGURE 1: An example of a salt fog chamber.


FIGURE 2: An example of a humidity chamber.

MIL-STD-8831 is the military standard for electronic devices such as integrated circuits. Every part had to meet that standard in order to be categorized as a mil part. The practice of dropping the “883/C” specified parts in favor of the more available, less costly, less tested (if at all) 0 to 70°C commercial versions of a part is a familiar routine for military contract circuit designers. But the question of how to validate the use of these components must be readdressed with every new design.

Are the parts to be tested for yield as part of incoming inspection, or prior to shipment from the vendor? Are they to be sent out to an external “up-screening” lab? Can the assumption be made that the part itself has not changed, but is simply no longer tested/guaranteed by the manufacturer? Further, with yield expectations high, there may be consideration given to install and then test only the next higher assembly (NHA). Investigations into manufacturing practices and recent historical failure data may assist in such decisions.

At the component level, up-screening is the safest way to assure that no changes have taken place in even the most reliable methods of manufacture and material acquisitions. Up-screening refers to testing for the sake of finding the yield (100% minus % failed parts). Extended screening, also known as life cycle screening, will allow for some assurance that the parts will have long-term reliability. This practice is known as ruggedization.

Some of the tests that apply, often referred to as environmental stress screening (ESS), include thermal cycling, high temperature exposure, low temperature exposure, highly accelerated stress testing or screening (HAST), highly accelerated life testing (HALT), vibration, shock, humidity, salt fog, rain, explosive atmosphere, low pressure (altitude) and fungus, among others. Excluding HAST and HALT, those listed would be typical of environmental testing for a military contract design of a PCB or electronic unit.

Accelerated methods such as HAST allow simulating advanced aging of the device under test (DUT). HAST includes relative humidity (RH) of up to 98%, temperatures to 120˚C, with simultaneous pressure, versus a simple 80˚C temperature and 85% RH in a normal thermal chamber. HAST exposes equipment and parts to higher-than-specified levels, while HALT exposes equipment and parts from normal through to higher-than-specified levels.

Finite element analysis (FEA) is a modeling/simulation alternative, or more accurately, accompaniment to the tests, and is used to show current reliability or to improve ruggedization of a part. MIL-HDBK-217 is a widely used reliability prediction method for military equipment; here, failure prediction is calculated in terms of mean time between failure (MTBF). This reliability method is based upon known components as model elements, for which MTBF is inserted into the calculations as "typical." The models fall short in kind and in accuracy for new components. Test is therefore warranted.

Failure Analysis

Any failures resulting from testing can be subject to failure mode analysis. This typically includes both optical microscope inspection and microsectioning for scanning electron microscope (SEM) analysis of the part, in order to find the cause of failure. The failure modes can then be described as:

- Resulting from stress of a particular type.
- Being applicable only to a particular portion of the component.
- Possibly occurring only while other additional conditions are present.

Another failure would be an IC that exhibits internal opens or short-circuiting, but only over long periods of time. Here methods such as HALT will assist in mimicking the conditions evidenced by a part over an extended period of time. SEM analysis may then reveal that the overlay of dissimilar metals has caused intermetallic layer growth and fracture to form an open circuit, or tin whisker growth to form a short circuit.

A simple failure example would be a printed circuit board fracture, with failure mode occurring only during a combination of the following criteria: a) when the heavy heatsink resides on the outer 2″ perimeter of the board; b) when the board endures temperatures below -20˚C; and c) when subjected to a 20 g shock.

Failure analysis capabilities of a high-end environmental lab often include:

FIGURE 3: An example of thermal shock test equipment.

- Optical microscopy with digital imaging.
- Microsectioning.
- SEM analysis.
- Fourier transform infrared spectroscopy.
- Ion chromatography.
- Wetting balance.
- Transmission x-ray imaging.
- Shear testing.
- Reduced oxide solderability activation (ROSA).
- Ultra-violet visible (UV-Vis) spectroscopy.
- Sequential electrochemical reduction analysis (SERA).
- Level 1 component analysis.

Environmental labs, such as those found at the American Competitiveness Institute (ACI), provide such exposure testing. Capabilities can include:

- Thermal cycling test, from 65°C to 155°C, with a ramp rate of 10°C/minute maximum.
- Thermal shock testing, from -75°C to 160°C in less than 5 sec switching time.
- High temperature exposure, to 160°C.
- Low temperature exposure, down to -75°C.
- HAST temperature/humidity/pressure testing, with temperatures to 143°C max, humidity 75% to 98% RH, with pressure from .02 to .2 megapascals (maximum similar to 2 atmospheres).
- Vibration testing to 1 pound-weight unit under test (UUT), sine, sine-sweep and random humidity/heat, typically 85% RH/85°C, capable of up to 95%/-15°C to 90°C.
- Salt fog.
- Rain.

From Commercial to Mil

As part of the Standard Missile program, the Electronics Manufacturing Productivity Facility (EMPF) has up-screened components under the Electronic Miniaturization for Missiles Application (EMMA) program. The EMPF, managed by ACI, houses the Navy's Center of Excellence for Electronics Manufacturing, and has, as its charter, the continued improvement of industry manufacturing processes for PCBs.

Vibration and -55°C to 125°C thermal cycling was performed for components with various packaging types, including SOT, TQFP, PBGA, TBGA, flip chip and LFCSP, while mounted on three different substrates. Other devices, including amplifiers, A/D converters, power MOSFETs and memory components, were subjected to environmental exposures followed by functional testing and analysis.

Data sheet comparison of a MIL-STD-883 specified part with its commercial equivalent may reveal the limited nature of intended use for the commercial part. However, the "full mil" version is usually not required either. The specifications must be decided individually, as they apply to the circuit, military platform or intended environment.

FIGURE 4: EMMA test vehicle boards.

With the critical nature of the desired part (883 specs or similar, that are absolutely necessary) having been established, ruggedization can be limited in scope. The particular application in the circuit, the position with respect to thermal dissipation techniques and the mission duration further limit or add to the testing required. Thermal cycling is a typical starting point, as real aging includes exposure to daily changes in temperature. A second choice is often vibration, as it will reveal the mechanical fragility of an item, particularly its packaging.

In choosing a COTS part, the electrical characteristics may fall short of its military predecessor. However, if the part is intended as part of a redesign, it may be acceptable to use the less critically specified part while allowing associated new circuitry to make up the balance of tolerances that may actually have been placed on the next higher assembly circuit. The tradeoffs involved in choosing similar, rather than identical, replacements are discussed in other publications.

The ruggedization of COTS items, at the component or the device/unit level, allows for increased reliability; i.e., an increased MTBF. Cost and labor benefit from less frequent downtime for repair. However, the ability to remain in mission-ready status for extended tours of duty is the real goal.

Up-screening, though a time-consuming process whose logistics necessitate the cooperation of manufacturers, distributors, test facilities and assembly schedules, can be reduced through strict investigation of the platform's requirements. The key to successful use of COTS parts is extracting the actual requirements for the military platform – determining which specifications truly must be "mil spec." For replacements, should a drop-in COTS item be unavailable, then a redesign of associated circuitry (to alleviate the critical nature of the single part) may be an option, thus maintaining the integrity of the next higher assembly. But when the COTS part itself must adhere to certain specifications, these parameters must be verified. Up-screening for yield before assembly and age-simulation for failure rate prediction provide the reassurance of risk reduction.

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References

1. MIL-STD-883, whose characteristics were designated within a typically six-page long data sheet, including how tested/proved along with applications, had operating temperature range -55°C to +125°C, etc. MIL-STD-883 is currently at rev F.