

A Rational Approach to the Use of Plastic ICs

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The use of Plastic Encapsulated Microcircuits (PEMs) is becoming increasingly prevalent. In 1992, the Reliability Analysis Center (RAC) issued a comprehensive report¹ on the cost, availability, quality and reliability of PEMs. The data presented in that report focused on commercial applications (ground and automotive electronics) because of the widespread use of PEMs in those applications. There is now a movement afoot in the world of government electronics to use PEMs in military, air traffic control, and even space applications. The movement is based upon some very compelling arguments in favor of PEMs over MIL-grade ceramic-packaged ICs:

- Reduced acquisition cost - in some cases an order of magnitude or more
- Significant weight reduction - which translates into increased capability and lower operating/fuel costs for avionics platforms
- Greater part selection and availability
- A larger potential supplier base
- Improvements in the processes, materials and reliability of PEMs so that they now rival or exceed the quality of hermetic ICs.

As attractive as PEMs may be, and as ubiquitous as they may ultimately become, their use in military electronics or in other severe environments should not be undertaken without considering the additional design constraints necessitated by their use.

Plastic ý Panacea

With the exception of loss of hermeticity due to package seal or feedthrough failure, PEMs can suffer from the same infant mortality or assignable cause failure mechanisms as do hermetic parts. In addition, PEMs are susceptible to wearout mechanisms which may be problematic within the useful life of the system. These PEM-unique mechanisms include corrosion due to moisture penetration of the plastic; wire-bond fracture and chip-outs; die cracking (predominant in larger PEMs); metallization shearing and thin film cracking; and stress-induced electrical leakage. While the first of these, corrosion, is still a concern, today's PEM manufacturers consciously reduce the extractable halide content of their polymers and reduce the phosphorus content in their glass passivation to make PEMs less susceptible to corrosion. The thermo-mechanical issues related to temperature cycling, however, are significant. It should also be noted that PEMs have higher thermal resistance (θ_{JC}) than do ICs in ceramic packages.

Other factors which must be considered when deciding to use plastic parts include the fact that not all device types are available in plastic packages. This is especially true of "leading edge" rf parts and hybrid designs which frequently are chosen for DoD systems. Further, a new set of vendors must be evaluated for their ability to deliver a product which will be reliable in the intended application. Since there is no mandated standard for testing and screening, other methods have to be developed to evaluate reliability. Part selection becomes more difficult and the cost of the evaluation must be factored into the decision to "go plastic." There's no way around it: caveat emptor applies.

A Conservative (but Rational) Approach

All of the wearout failure mechanisms associated with plastic packaging are environmentally induced.

Therefore, the alternatives available to the designer to ensure PEM reliability are (1) controlling the environment using conservative design rules, and (2) selecting parts based upon their ability to withstand more severe environments.

One set of design rules which will provide high confidence that well-made PEMs will not experience wearout within the useful life of most systems (10,000 operating hours, or ten years) is (Ref. 2):

- Storage and use at 30% maximum relative humidity
- 0°C - 70°C (case) maximum operating temperature range
- Minimum on-off cycling; constant power-on preferred
- Adherence to manufacturers' recommended thermal derating requirements to account for increased thermal resistance
- 5 volts bias maximum
- Electrical derating the same as for hermetic devices

Of course, these criteria may not always be feasible in the intended application and alternative (2) may have to be invoked.

The method described in reference 2 which has been used to evaluate the reliability of plastic parts in "uncontrolled" environments consists of seven steps:

1. Defining the application environment
2. Determining the relevant failure mechanisms
3. Determining the characteristics of the failure distribution in time for each mechanism
4. Determining the acceleration factors to relate environmental stress from the accelerated life test to the application environment
5. Determining the maximum allowable cumulative percent defective at times of interest (e.g., warranty period, equipment design life)
6. Calculating the actual cumulative percent defective at the times of interest from the accelerated life test data
7. Determining the acceptability of the parts by comparing results of Steps 5 and 6.

Implicit in the use of this method is the availability of accelerated life test data. The primary tests used to accelerate end-of-life are temperature cycling and some form of humidity testing (such as temperature-humidity-bias testing in an autoclave). Reputable vendors perform these tests periodically to determine the reliability of their product, and most are willing to share the test data with prospective buyers. (A good rule of thumb is: No data, no purchase order!)

It may not be obvious, but the more difficult steps are the first, fourth and fifth. Assumptions must be made about the operating time, on-off cycles, temperature excursions, and relative humidity. Despite the fact that the log-normal is a well-accepted model for wearout distributions, the acceleration factors chosen may be contentious and they have a large impact on the result of the analysis. Determination of an acceptable defect level is a function of system requirements, warranty costs and customer "good will." Engineering judgment is a significant factor.

Some additional words of caution are necessary. First, while PEM manufacturers may claim that their parts are usable in surface mount applications, high temperature manufacturing technology (such as IR reflow or vapor phase soldering) can cause cracks in the packages due to rapid expansion of entrapped moisture; a pre-bake of the parts, or storage in dry nitrogen, is necessary. Second, the evaluation of vendor data is not a one-time occurrence, but should be undertaken periodically. Development of a cooperative working relationship with the vendors and monitoring of their processes is vital. Third, wherever possible PEMs should be chosen so that hermetic packaged devices of the same style are available in the event that a problem arises. Finally, in no case should thermal derating criteria be relaxed.

Designing for Plastics

In summary, plastic parts from reputable vendors may be used without concern if the environment is controlled. They may also be used in "uncontrolled" environments if adequate precautions are taken in the form of conservative design guidelines and evaluation of vendor data.

References:

1. "Plastic Microcircuit Packages: A Technology Review - 1992", Reliability Analysis Center, Rome, NY.
2. Dix, G.E., "Report on the Use of Plastic-Encapsulated Microcircuits in Commercial Designs," Westinghouse Electric Corporation, July 1991.

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