START
Selected Topics in Assurance Related Technologies
Volume 2, Number 1

Plastic Encapsulated Microcircuits (PEM's)

Summary:

A Plastic Encapsulated Microcircuit (PEM) uses organic packaging material, either transfer molded or coated, for environmental protection. This material is in direct contact with the active element or an inorganic barrier layer. This is in contrast to metal or ceramic packaging, which has a hermetically sealed cavity and no active element or organic barrier interface with the package material. The vast majority of PEM usage has been in commercial, telecommunication, automotive and industrial applications. Military usage has been generally limited to high shock (munitions) and Nondevelopmental Items (NDI) or Commercial Off-The-Shelf (COTS) applications.

The major advantages that can be gained from their use are:

- Greater availability (especially surface mount packaging)
- Lighter weight
- Lower cost (high volume procurement)

Concerns associated with their increased usage, especially military, include:

- Uncertainty regarding their long term reliability in harsh environments
- Lack of reliability/quality assurance procedures
- Insufficient military environment reliability data (operating and storage)
- Existing OEM procurement expertise

The concern over the lack of R&QA procedures is abating because of the following specification activity:

- Automotive Electronics Council (Chrysler, Delco, Ford) CDF-AEL-Q1000, “Stress Test Qualification for Automotive Grade Integrated Circuits” (released 9 June 1994)
- MIL-PRF-38535 “Integrated Circuits (Microcircuits) Manufacturing, General Specification for” which includes provisions for PEMs
- JEDEC Standard 26 “Plastic Packages for Use in Rugged Applications” (being prepared)

Usage of early PEM’s (1970’s) was discouraged because of high failure rates. Table 1 summarizes predominate failure mechanisms and causes experienced in those devices.

However, major improvements have been made in the fabrication of PEM’s. The following lists some of the processes/materials/testing that have been improved:

- Materials - increased epoxy molding compound (e.g., resin) purity
- Material attributes - enhanced CTE, glass transition temperature, fracture toughness, moisture desorption, adhesion, viscosity, mold release, appearance
- Lead frame design
- Die coatings - high quality device passivation (i.e., silicon nitride)
- Die design
- Material characteristics - reduced chloride and other halides, flame retardant stability, ion scavengers
- Fabrication equipment
- Testing procedures - Highly Accelerated Stress Testing (HAST), autoclave, moisture absorbance, C-Mode Scanning Acoustic Microscopy (C-SAM), dye penetration

Table 1: PEM Failure Mode/Mechanisms (Circa 1970’s)

Failure	Cause
Wire bond intermittency/lifting	Coefficient of thermal expansion (CTE) differences
Wire/metallization corrosion	Moisture/contamination
Voiding/poor adhesion	Processing/materials
Data/soft errors	Alpha particles (filler material)

Recent data show that the failure rate of plastic packages has decreased from about 100 failures per million device hours in the 70's to those shown in Table 2.

Table 2: Average Early Life Failure Rates of PEMs

Application	Failure/10^6 Hours
Computer /Test Equipment	0.0007
Commercial Aircraft	0.04 - .07
Automotive	0.1 - 0.7

Status:

Today the most popular molding compound is based on epoxy novolac resin. The basic composition contains, by weight, 15-30% epoxy resin and hardeners, 60-80% fillers, 1-7% pigment, mold release, coupling agent and stress absorbers, 1-5% flame retardant, and 1-2% catalyst. Reduction of chloride and other halides in the basic epoxy composition, stable flame retardants and ion scavengers have essentially eliminated aluminum wire and chip metallization corrosion problems. Single bit loss and soft errors have been reduced through reduction of alpha emitting elements and by barrier coating of the integrated circuit (IC) die.

Delamination or "popcorning" associated with surface mount technology (SMT) using various soldering techniques is understood and can be controlled. Techniques used include baking the finished part and sealing it within an airtight plastic bag with a dessicant to reduce moisture levels. At the device level, delamination effects can be reduced by perforating leadframes, decreasing filler particle size, and stamping leadframes to eliminate burr formation sites that contribute to stress concentration.

PEMs are used in harsh environments, such as automotive under-hood applications and commercial avionics systems. The mechanical ruggedness of plastic packaged devices makes them attractive in high shock and vibration applications that can damage ceramic packages.

To ensure PEM reliability, it is important to carefully review each vendor, his manufacturing process and reliability test results, and the customer base of each prospective plastic IC supplier prior to use. Additionally, PEM's are typically available and guaranteed by the vendor over the commercial temperature range of 0-70°C, to vendor electrical parameters. The industry has had success with the use of these devices at greater temperature extremes. However, to ensure performance it is necessary for each OEM, to not only certify each vendor, but also to verify that each device will satisfy its intended application. For example, temperature can affect device parameter limits (e.g., speed) or reliability (e.g., excessive current density).

Some items that have been proven to enhance reliability that can be used in evaluating the integrity of a supplier of plastic parts include, but are not limited to:

- reduced phosphorus levels in passivation
- dual layer passivation in critical cases
- perforated frames
- benign (non-ionic) cleaning of frames after molding
- use of copper frames
- reduced stress trim and form
- corrosion resistant mold compounds
- nitride passivation
- control/elimination of ionic contamination
- comprehensive reliability program

Today there is general acknowledgement that there have been significant improvements in plastic encapsulated devices. Although their failure mechanisms have not been totally eliminated, they have been reduced by orders of magnitude.

About the Reliability Analysis Center

The Reliability Analysis Center is a Department of Defense Information Analysis Center (IAC). RAC serves as a government and industry focal point for efforts to improve the reliability, maintainability and quality of manufactured components and systems. To this end, RAC collects, analyzes, archives in computerized databases, and publishes data concerning the quality and reliability of equipments and systems, as well as the microcircuit, discrete semiconductor, and electromechanical and mechanical components that comprise them. RAC also evaluates and publishes information on engineering techniques and methods. Information is distributed in data compilations, application guides, data products and programs on computer media, public and private training courses, and consulting services.

Located in Rome, NY, the Reliability Analysis Center is sponsored by the Defense Technical Information Center (DTIC). Since its inception in 1968, the RAC has been operated by IIT Research Institute (IITRI). Technical management of the RAC is provided by the U.S. Air Force's Rome Laboratory (formerly Rome Air Development Center) at Griffiss AFB.

When PEM attributes are discussed, it becomes obvious two camps exist, as illustrated in Figure 1. However, both camps agree that the reliable application of PEMs requires the use of quality vendors and the characterization of PEMs for specific applications.

The procedure described in Figure 2 can be used for the how, when and where determination for plastic packaged devices use.

The approaches used in the automotive specification CDF-AEL-Q1000 and MIL-PRF-38535 should be evaluated for use in procuring PEM's.

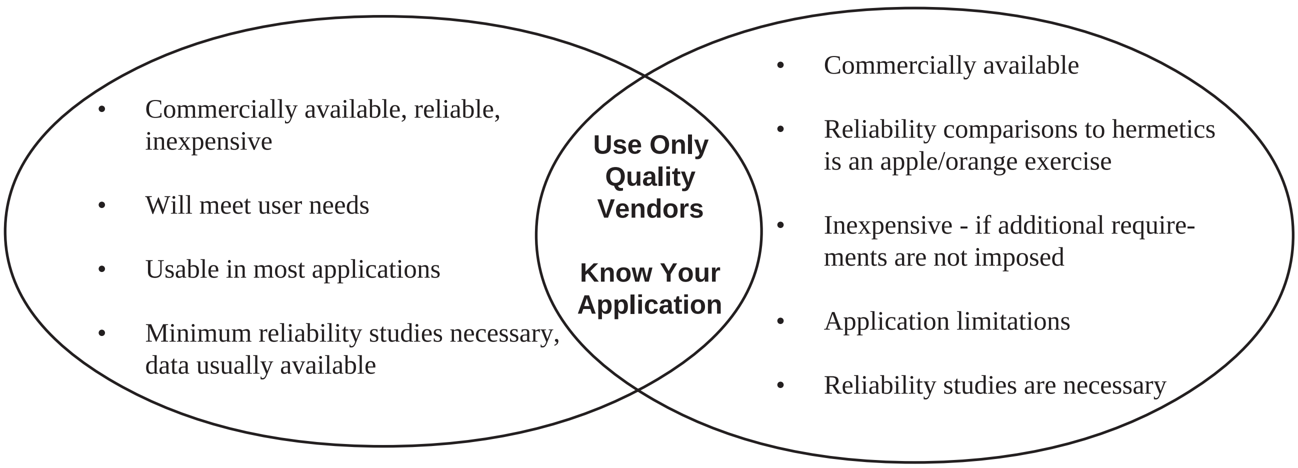

Figure 1: PEM Attributes

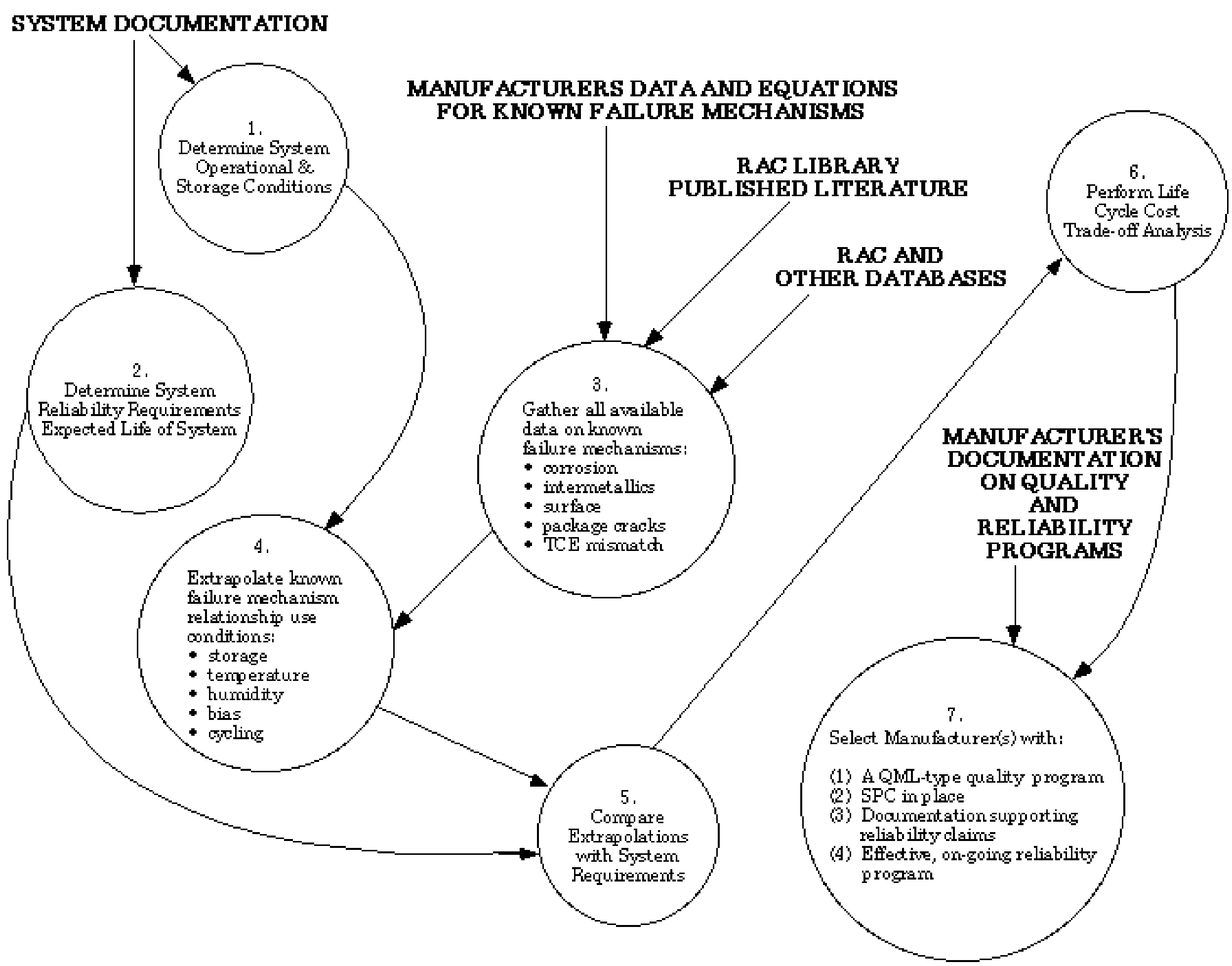

Figure 2: Process Flow for PEM Use Determination

Bibliography:

PEM Specifications:

MIL-PRF-38535 — General Specification for Integrated Circuits (Microcircuits) Manufacturing

CDF-AEC-Q100 — Stress Test Qualification for Automotive Grade Integrated Circuits

JEDEC - Standard 26 — Plastic Encapsulated Packages for Use in Rugged Applications

Books:

Plastic Packaging of Microelectronic Devices, L.T. Manzione, AT&T.

Plastic Encapsulated Microelectronics: Materials, Processes, Quality, Reliability and Applications, M. Pecht, L. Nguyen and E. Hakim.

Reports:

"Plastic Microcircuit Packages: A Technology Review," (92 PEM (Plastic Encapsulated Microcircuits), RAC Publication, M. Priore and J.P. Farrell.

"Reliability Considerations for Using Plastic - Encapsulated Microcircuits in Military Applications," Harris Semiconductor, W.L. Schultz and S. Gottesfeld.

MIL-HDBK-179(ER), Microcircuit Applications Handbook.

Conference/Workshops/Papers:

Proceedings of 1993 and 1994 Advanced Microelectronics Qualification/Reliability Workshops.

"Reliability Data Supports PEMs in Many Military Applications," W. Schultz and S. Gottsfeld, Military and Aerospace Electronics, January 1995.

Future Issues:

RAC's selected topics in assurance related technologies (START) are intended to get you started in knowledge of a particular subject of immediate interest in reliability, maintainability and quality. Some of our upcoming topics being considered are:

- Commercial Off-the-Shelf Equipment
- Reliability Predictions
- Part Selection and Control
- Mechanical Reliability
- Software Reliability

Please let us know if there are subjects you would like covered in future issues of START.

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