

Open-Cavity Plastic Packages: A Robust IC Packaging Solution for High-Reliability Applications

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Abstract

Fast-turn prototype package assembly is frequently employed for rapid IC design verification. Open-cavity plastic packages (OCP) are an attractive assembly option when commercial off-the-shelf (COTS) prototype packages are not available. Any existing IC plastic packages, whether dummies, electrical test rejects or excess inventory, can be quickly converted into robust open-cavity packages, ready to be assembled with new die, creating new packages that will fit an established footprint. This allows them to be easily inserted into test sockets and boards, so that no retooling or redesign is required.

OCP is also a practical option for production when no onshore sources exist for a company's required plastic package assembly. This paper will delve into a case study example that details the process by which QP Technologies' OCPs were selected and qualified for avionics ASIC provider DEI when its prior package/assembly provider went out of business. The resulting packages passed MSL-3 solder stress tests *with results equivalent to factory-fresh parts*.

Key words

IC assembly, IC packaging, prototype, quick-turn, robust

I. Introduction

Semiconductor makers invest significant resources in the development and manufacture of their devices, including packaging and assembly techniques that accommodate their material, mechanical, electrical, reliability, and footprint specifications. They must meet very tight time-to-market windows as cost-effectively as possible.

When commercial off-the-shelf (COTS) prototype packages are not available, QP Technologies can convert any existing IC plastic packages, whether dummies, electrical test rejects or excess inventory, into one of its OCPs, ready to be assembled with new die. Converting a range of popular package types, sizes and pin counts into an OCP option creates new packages that will fit into a manufacturer's already-established footprint, using existing test sockets and boards. This saves cost as well as time to market for a chipmaker's products.

OCP is also an attractive option for production when no onshore sources exist for the particular plastic package

assembly since lead time and International Traffic in Arms Regulations (ITAR) constraints prohibit offshore assembly. When avionics ASIC provider Device Engineering Inc. (DEI) encountered this problem, in order to meet its crucial production schedule, reliability requirements, and ITAR supply constraints, the company selected QP Technologies' OCP approach as an effective solution.

II. What Is OCP?

OCP is analogous to a high-quality "pre-owned car." Using OCP allows reclaiming of existing "dummy" packages, e.g., electrical rejects, test packages, or excess inventory. After removing plastic and existing die, down to the copper, a new package is then built within the OCP shell. OCP is well suited for cost-sensitive projects or those that only require small batches.

Another key application for OCP is to employ it as an interim solution, optimizing the package and working out any kinks, before transitioning to Open-molded Plastic

Package (OmPP®), QP Technologies' patented family of pre-molded, air-cavity QFNs.

OCPPs are a type of quad flat pack (QFP) leaded package that can withstand hundreds to thousands of thermal cycles, at temperatures between -40 °C and 125 °C. The OCPP concept is time-tested and proven as a means of combating package obsolescence. Military vessels such as long-serving battleships, for one example, have benefited from the use of OCPP packages to preserve existing device designs and footprints, keeping the ship from having to be dry-docked.

This long-life implementation of electronic components is a well-established pattern for military and aerospace applications. In service for decades, they require devices with the quality and robustness to remain operational over the end product's lifetime. OCPP-type packages have proven their resilience for this market.

III. Meeting MSL Requirements

The JEDEC moisture sensitivity level (MSL) is a key characteristics of plastic encapsulated microcircuits (PEMs) that defines the storage and handling constraints during the manufacturing process for a particular PEM product. The MSL rating also determines the preconditioning stress level for the package reliability tests that are performed to qualify a PEM product for release to production.

The joint IPC/JEDEC J-STD-020E Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid-State Surface-Mount Devices standard [1] is used to determine what classification level should be used for initial reliability qualification. Once identified, the PEMs can be properly packed, stored and handled to avoid subsequent thermal and mechanical damage during the assembly solder reflow attachment and/or repair operation.

The standard establishes the time period in which a moisture-sensitive device can be exposed to ambient room temperature. The MSL floor life ratings are shown in Table I. The definition of "floor life" is the allowable period of time storage at ≤ 30 °C, 60% RH before degradation occurs.

IV. DEI's Challenge

DEI sought out OCPP technology as a solution for production assembly of its 64-lead thin QFP (TQFP) 10 x 10 mm ePad product when its prior onshore assembly provider ceased doing business – in turn, creating a challenge for DEI's customer. Once DEI was able to source a quantity of suitable dummy IC packages (containing no die) from an offshore supplier, QP Tech converted them to OCPP,

developing the assembly process and materials that achieve DEI's required package performance.

The IC was characterized for MSL, as determined by J-STD-020, and qualified via environmental stress-based accelerated reliability tests. The IC was qualified in the end product and has entered production.

TABLE 1. MOISTURE SENSITIVITY LEVEL DEFINITIONS

MSL Rating	Floor Life
1	Unlimited (30 °C less than 85% RH)
2	1 year
2a	4 weeks
3	168 hours
4	72 hours
5	48 hours
5a	24 hours
6	Mandatory bake before use

V. QP Technology's Methodology

To find the right process for DEI's specifications, QP Technologies experimented to evaluate various OCPP types and configurations. First, 64-lead TQFP packages were opened and sent out to plating to protect the copper with a nickel-gold (Ni+Au) alloy. Nickel acts as a diffusion barrier, with gold protecting the circuit from elements.

Die-attach epoxies were then evaluated, including Ablebond 84-11mi and H70E – both electrically conductive epoxies with silver particles. In both cases, epoxy bleed-out later created delamination between encapsulation and surface of the package, with parts failing solder stress tests as detected by confocal scanning acoustic microscopy (CSAM) imaging.

As the design comprised multiple down-bonds, it was essential that the die attach pad be free of delamination from solder stress. Experiments were performed that demonstrated that the die attach pad with its native copper and Ag spot plating yielded better solder stress performance compared to those with nickel-gold plating. Thus, the extra plating step was eliminated.

Next, another design-of-experiments (DOEs) set was started, working with unplated OCPP packages. Various epoxies were evaluated, and a newly formulated product, Ablebond QMI529HT, was selected. This epoxy is designed specifically for copper, features minimal bleed-out, and doesn't affect the adhesion of encapsulation to the copper, as

CSAM indicates. The epoxy is also compliant with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment directive (RoHS). In addition to EU RoHS guidelines, QP Tech adheres to California's own RoHS laws governing electronic devices sold in the state.

Once the optimal epoxy and OCPP type were determined, QP Technologies pursued multiple iterations to develop the ideal recipe for building packages that would pass all-important MSL testing. The packages passed **MSL-3 / 235 °C solder stress tests with no evidence of delamination, with results equivalent to factory-fresh parts.**

To ensure process repeatability, a traveler was created to document the recipe, including the exact steps and order in which they must be performed – epoxy type, how the package is opened, wirebonding process, encapsulation, material, etc.

First, a lot of 50 packages was developed for DEI to perform pre-compliance reliability testing. After they passed, several hundred packages were assembled as a qualification lot. These were production screened by DEI, including temperature cycling, burn-in and electrical tests. Finally, the leads and ePads were hot solder dipped to remove the native matte tin plating. Several of the screened parts were submitted for qualification testing. Fig. 1 illustrates the qualification tests and flow. The reliability tests were performed with MSL 4 / 235 °C preconditioning per the product requirement.

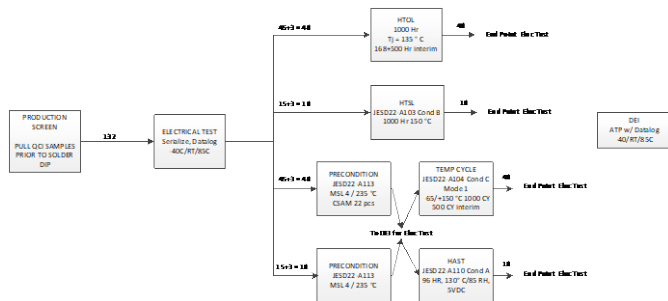


Fig. 1 Qualification test plan for 64-QFP OCPP

VI. Results

The OCPP packages were tested and qualified for production with results meeting the requirements of factory-fresh parts. The tables shown in Fig. 2 provide further insight into the qualification testing process, conditions and results. Parts were subjected to a range of component level environmental stress tests and conditions. Not only did the parts pass these tests, but also the end item equipment production and final

assembly qualification tests. This illustrates the robustness of the OCPP solution.

Package Assembly Tests

QCILot				
Test	Min Limit	SS	Range	Result
Die Shear	2.5 kg	6 units	12.3 – 27.8 kg	Pass
Destructive Wire Pull	4.0 gr	2 units 12 wires ea	7.4 – 14.3 gr	Pass

Tin Mitigation SnPb Hot Solder Dip Tests

HSD of "Dummy Packages" no die				
Test	SS	Notes	Result	
CSAM Inspection	4 units	No delamination	Pass	
XRF	3 units	SnPb% OK	Pass	
Composition/Thickness	4 readings ea	Thickness OK		

QCILot (1)						
Test	Condition	Duration	Sample Size	Reject	Date	Notes
Electrical ASL Test	DC Characteristics and Function	n/a	132	0	4Q20	
RF Test	40 °C, 25 °C, +85 °C RF Function	n/a	132	0	4Q20	
PC Precondition	JESD22-A113	24 hr	66	0	4Q20	
PC+HAST	MSL 4 / 235 °C, CSAM, qty 22 JESD22-A110 Cond A 130 °C, 85% RH, Biased, Cycled Power	96 hr	18	0	4Q20	
HTOL	883 Gap C TM1005 Tp > 125 °C, Ta = 90 °C, 5 V Constant Bias	1000 hr	47	0	4Q20	(2)
HTSL	JESD22-A103 cond B Ta = 150 °C	1000 hr	18	0	4Q20	
PC+TC	JESD22-A104 cond C Mode 1 -65 °C to +150 °C	1000 cy	48	0	4Q20	

Notes:
 1. QCIL samples are without SnPb HSD.
 2. One of 48 HTOL samples was pulled at the HTOL 500 hr interim test due to a non-relevant failure. It failed electrical continuity due to lead / socket issues. The leads were cleaned with IPA/sonic and the unit then passed electrical test but was too late to return to the oven.

Fig. 2 Qualification test summary

VII. OCPP Options

The above results illustrate what worked best for DEI's requirements. A wide variety of options can be implemented using open-cavity plastic packages. Once the molding compound is removed and the precious metal surfaces cleaned, exposing the die attach page and bond fingers, a variety of encapsulation approaches can be utilized. Fig. 3 illustrates some of these options.



Fig. 3. Encapsulation options for OCPP

VIII. Conclusion

The relatively rapid OCPP development and qualification time, as compared to offshore licensing, avoided a gap in the end-item customer's production and delivery schedule.

QP Technologies is currently developing overmolded parts (OmPPs) for DEI from scratch, which is a long-lead-time process. However, due to their high performance and reliability, the OCPPs continue to be produced concurrently to ensure that DEI has access to a consistent, uninterrupted supply of parts. In essence, OCPPs serve as a valuable and reliable insurance policy for DEI and its customers.

References

- [1] IPC/JEDEC Standards & Documents:
https://www.jedec.org/document_search?search_api_views_fulltext=j-std-020