QPTECHNOLOGIES
A DIVISION OF PROMEX INDUSTRIES

TECHNOLOGY BACKGROUNDER

Durability and Cost Benefits Drive Mil-Aero Demand for OCPP

Chip packaging for military and aerospace applications must meet stringent requirements for robustness, longevity and cost savings. Open-cavity plastic packaging has a proven history and a bright future for this market.

Executive Summary

Ceramic packages were, for many years, the option of choice for semiconductor prototype assembly, particularly in military-aerospace applications. They are able to withstand high temperatures and can be hermetically sealed. However, they can be costly and, while they allow for rapid assembly of first samples, the final product is typically a plastic package, so the ceramic prototype doesn't offer an accurate representation. This need for a better, more viable alternative to ceramic was one of the catalysts that gave rise to open-cavity plastic packaging (OCPP).

OCPP is the ideal platform for new IC prototypes because the packages are mechanically and electrically identical to a chipmaker's future transfer molded production parts. They can be prepared in advance and stored for assembly as soon as the wafers and/or die are ready.

OCPP is made to withstand the test of time. This paper looks at the benefits and advantages of OCPP and describes a real-world project that illustrates why utilizing OCPP for device designs offers a cost-effective solution for low- to mid-volume packaging destined for mil-aero end applications.

The Need for a Secure Supply

Semiconductor manufacturers have always strived to optimize utilization of their fab, packaging and assembly resources. The global pandemic and subsequent supply-chain issues that began in 2020 created shortages that have elevated the need to maximize these resources – and to revisit or take a new look at existing solutions with attractive time and cost benefits.

When a project or customer deadline looms, outsourced semiconductor assembly and test (OSAT) providers may not have the resources to provide the parts needed in a timely manner. OSATs aren't structured to support product development and device verification processes. Smaller, more nimble companies can have open-cavity plastic packages readily available for quick-turn assembly of prototypes and small quantities of packaged devices.

This challenge becomes even more pronounced when the devices in question are developed for military or aerospace end products, which have stringent requirements with respect to long-term robustness and functionality. In the U.S., security restrictions also require that assembly be provided by a stateside supplier, as most OSATs are located offshore.

What Is OCPP?

Reliability data show that OCPPs have long-term value in both their ability to withstand challenging natural environments and to guard against obsolescence. When a military, avionics, or aerospace end product needs devices whose packages may no longer be available from a previous provider, redesigning is rarely an option. The manufacturer needs packages that can be quickly developed to accommodate existing functionality and fit existing package footprints.

But what, exactly, do we mean when we talk about OCPP?

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.

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. Figure 1 illustrates some of these options.

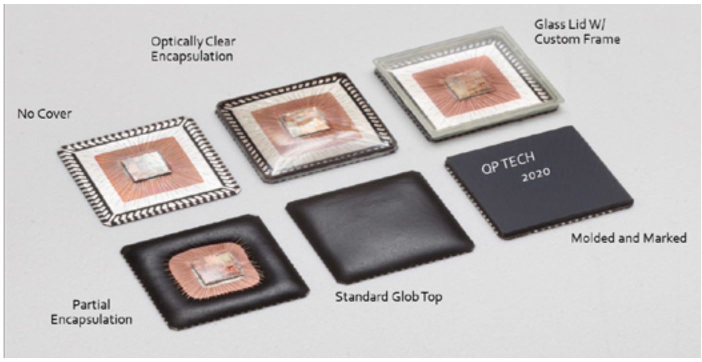

Figure 1. Encapsulation options for OCPP

OCPP is analogous to a high-quality "pre-owned car." Using OCPP 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 OCPP shell. OCPP is well suited for cost-sensitive projects or those that only require small batches.

Another key application for OCPP is to employ it as an interim solution, optimizing the package and working out any kinks, before transitioning to open-molded plastic packages, which enable rapid turnarounds for prototype packaged devices. Die designers are often pushed to validate the performance of their new designs as quickly as possible. The time-to-market is often paramount. OSATs' infrastructure and geographical location make challenging for them to support quick-turn prototyping for U.S.-based semiconductor design firms. With the availability of open molded plastic packages, companies with flexible assembly operations can provide the support needed.

Meeting MSL Requirements

The JEDEC moisture sensitivity level (MSL) rating is a key characteristic 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 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. MSL floor life ratings are shown in Table 2. The definition of "floor life" is the allowable period of time storage at ≤ 30 ˚C, 60% RH before degradation occurs.

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

Table 2. MSL definition

A Real-World Example

As noted earlier, OCPP is an attractive option for production when no onshore sources are available for a particular plastic package assembly, and lead time and International Traffic in Arms Regulations (ITAR) constraints prohibit offshore assembly. When avionics ASIC provider Device Engineering Inc. (DEI) ran into this problem, QP Technologies' OCPP approach was an effective solution for DEI's crucial production schedule, reliability requirements, and ITAR supply constraints.

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 Technologies 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.

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.

Various die-attach epoxies were then evaluated. These included Ablebond 84-1lmi 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 repeatability of the process, 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, the wirebonding process, encapsulation, material, etc.

First, a lot of 50 packages was developed, on which DEI performed pre-compliance (confidence) reliability testing. After passing this testing, 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. Figure 3 illustrates the qualification tests and flow. The reliability tests were performed with MSL 4 / 235 °C preconditioning per the product requirement.

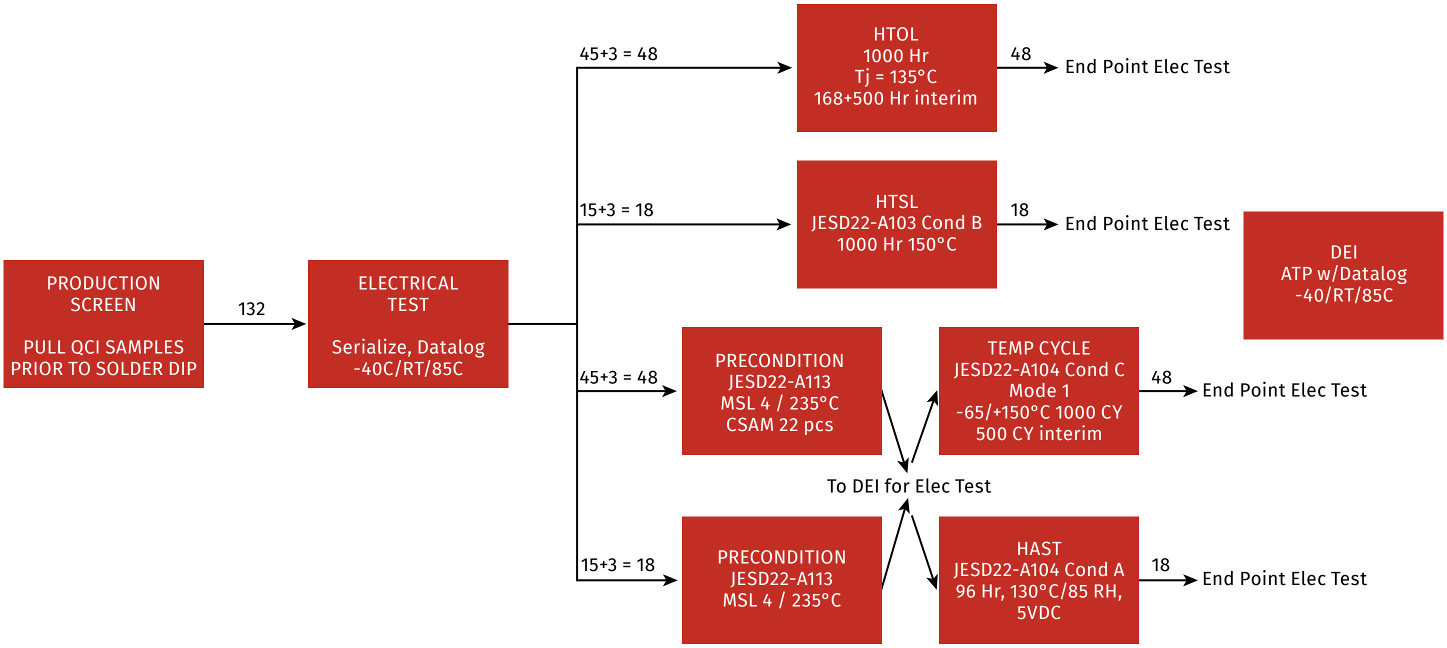

Figure 3. Qualification test plan for 64QFP OCPP

DEI Project Results

The OCPP packages were tested and qualified for production with results meeting the requirements of factory-fresh parts. The tables shown in Figure 4 provide further insight into the qualification testing process, conditions, and results.

Package Assembly Tests

QC Lot				
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 each	7.4-14.3 gr	Pass

Tin Mitigation SnPb Hot Solder Dip Tests

HSD of "Dummy Packages" no die			
Test	**SS**	**Notes**	**Results**
CSAM Inspection	4 units	No delamination	Pass
XRF Composition/ Thickness	3 units 4 readings each	SnPB% OK Thickness OK	Pass

QC Lot[1]						
Test	**Condition**	**Duration**	**Sample Size**	**Reject**	**Date**	**Notes**
Electrical ASL Test	DC Characteristics and Function -40°C, 25°C, +85°C	N/A	132	0	4Q20	
RF Test	RF Function -40°C, 25°C, +85°C	N/A	132	0	4Q20	
PC Precondition	JESD22-A113 MSL4 / 235°C, CSAM, qty 22	24 hours	66	0	4Q20	
PC+HAST	JESD22-A110 Cond A 130°C, 85% RH, Biased, Cycled Power	96 hours	18	0	4Q20	
HTOL	883 Grp C TM1005 Tj>125°C, Ta=90°C, 5 V Constant Bias	1000 hours	47	0	4Q20	(2)
HTSL	JESD22-A103 cond B Ta = 150°C	1000 hours	18	0	4Q20	
PC+TC	JESD22-A104 cond C Mode 1 -65°C to +150°C	1000 cycles	48	0	4Q20	

1. QCI 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.

Figure 4. Qualification test summary for OCPP

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 case study illustrates the robustness of the OCPP solution and highlights its effectiveness in a mil-aero application.

QPTECHNOLOGIES
A DIVISION OF PROMEX INDUSTRIES

A Division of Promex Industries
2063 Wineridge Place Escondido, CA 92029
858.674.4676 | www.qptechnologies.com | moreinfo@qptechnologies.com

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