

Clean Boards, Reliable Performance: Why PCBA Cleaning Is Critical Before Conformal Coating in Harsh Automotive Environments

For electronic designers and test engineers in the automotive sector, system reliability isn't optional, it's fundamental. From engine control units (ECUs) and transmission systems to advanced driver-assistance systems (ADAS) and battery management modules, today's automotive electronics must run flawlessly in extreme environments marked by heat, vibration, humidity and chemical exposure. These conditions accelerate failure modes, magnify material weaknesses, and challenge the durability of protective measures.

To meet these demands, conformal coatings are routinely applied to printed circuit board assemblies (PCBAs) as protective barriers. But before that coating is applied, there's a critical step that determines whether it will do its job: cleaning the board.

Proper PCBA cleaning before conformal coating is more than best practice—it's essential for long-term performance. Residual contamination under the coating can silently undermine adhesion, trap corrosive substances, and ultimately lead to electrical or mechanical failure. For automotive design and test professionals, understanding the importance of PCBA cleaning is key to achieving reliability in high-risk environments.

Why Clean Before Coating?

Conformal coatings—acrylics, silicones, polyurethanes and parylenes—serve as vital defenses against environmental hazards like moisture, salt spray, and particulates. However, they only function as intended if they adhere uniformly to a clean surface. Even small amounts of contamination can cause serious issues:

- **Delamination and blistering** due to flux residues or oils that interfere with adhesion.
- **Trapped ionic residues** that migrate under high humidity, promoting corrosion and dendritic growth.
- **Voids and bubbles** from particulates or uneven wetting, which disrupt the coating's barrier properties.

When a coating does not adhere, the protection fails along with it. Test engineers often see higher-than-expected failure rates in Highly Accelerated Life Testing (HALT) or Highly Accelerated Stress Screening (HASS) or see variability during thermal cycling—all signs of contamination beneath the coating. These failures can result in costly rework, warranty claims,

regulatory scrutiny or even recalls. In critical systems like braking or collision avoidance, the consequences may include real safety risks.

Invisible Threats: What Contaminants Remain After Assembly

Even in clean manufacturing settings, contaminants can linger on PCBA surfaces after soldering:

- **Flux residues**, especially from no-clean or low-solids fluxes, may be sticky or acidic, affecting coating adhesion and long-term insulation.
- **Ionic residues** (e.g., chlorides, bromides, sulphates) can conduct current in the presence of moisture, causing leakage or corrosion.
- **Non-ionic contaminants**, including fingerprints, machine oils or silicone lubricants, can cause defects such as fisheyes or patchy coverage.
- **Particulates**—solder balls, dust, or machining debris—may create voids under coatings or become stress points under thermal or mechanical strain.

These contaminants are often microscopic and invisible to the naked eye or standard visual inspection. Yet under harsh conditions, they can degrade coating integrity and compromise reliability. In the automotive sector, where longevity and fault-free performance are mandatory, this level of risk is simply unacceptable.

Designing With Cleanability in Mind

PCBA cleaning shouldn't be an afterthought—it should be considered from the beginning of the design phase. Design choices directly affect cleanability, including:

- **Flux choice:** No-clean fluxes may reduce process steps, but they often leave residues that interfere with coating. If a board will be coated, cleaning is still typically needed—even with no-clean materials.
- **Component standoff height:** Low-clearance parts can trap residues underneath, limiting the effectiveness of cleaning fluids. Designers should factor in fluid flow and access when laying out components.
- **Material compatibility:** Conformal coatings interact differently with various surfaces. Residues can change surface energy, causing inconsistent wetting or poor adhesion.
- **Pad and trace layout:** Dense trace paths, complex geometries, and under-component voids can make cleaning difficult, especially in miniaturized or high-density designs.

Designing for cleanability reduces the chance of coating failure, streamlines production, and improves test pass rates. It's an important part of risk mitigation and quality assurance.

Test Engineering Insights: Catching Failures Before the Field Does

Test engineers are the last line of defense against field failures. Residual contamination can manifest as subtle but serious problems:

- **Intermittent failures** caused by leakage paths from ionic residues.
- **Electrical drift or instability** from corrosion beneath coatings.
- **Coating delamination or blistering** under thermal or humidity stress.

Contamination is often the hidden root cause of board failures uncovered during HALT, HASS, or field returns. Integrating cleanliness testing—such as ion chromatography or surface insulation resistance (SIR) testing—into standard protocols can help identify trends and improve upstream process control.

PCBA Cleaning Methods: Choosing the Right Approach

The best cleaning approach depends on board geometry, contamination type, coating requirements, and production volume. Common cleaning methods include:

Aqueous Cleaning

Widely used in high-volume automotive manufacturing, aqueous systems use saponifiers and deionized water to dissolve and rinse away flux and ionic residues. Proper rinsing and thorough drying are essential to prevent moisture from becoming trapped under coatings.

Solvent-Based Cleaning

Modern solvent cleaning uses engineered chemistries that dissolve both ionic and non-ionic contaminants. These fluids often evaporate quickly and leave no residue. They are ideal for precision or selective cleaning, particularly before conformal coating.

Manual or Spot Cleaning

Useful for rework or small batch production, manual cleaning with lint-free wipes and solvent is effective for cleaning specific areas—but consistency is harder to maintain, and results depend on operator technique.

Each method has its trade-offs in terms of capital investment, throughput, safety, and environmental impact. The cleaning process must be tailored to the application and validated to ensure coating compatibility.

Process Integration and Cleanliness Validation

Integrating cleaning into the conformal coating process isn't just about choosing the right chemistry, it requires a structured, validated process:

- **Process definition:** Cleaning parameters such as time, temperature, fluid flow and agitation must be clearly defined and checked.
- **Thorough drying:** Moisture left on a board can cause blistering, delamination or electrical leakage. When aqueous cleaning, use of controlled drying techniques, such as warm air knives or low-humidity ovens, is essential.
- **Cleanliness validation:** Objective cleanliness testing—such as ROSE (Resistivity of Solvent Extract), ion chromatography or SIR testing—should be routinely used to confirm process efficacy.
- **Post-cleaning protection:** Once cleaned, boards must be handled in a controlled environment to avoid recontamination prior to coating.

A well-integrated cleaning and validation system provides a solid foundation for coating success—and for the product's reliability.

Conclusion: Clean First, Then Protect

In automotive electronics, reliability starts with cleanliness. No conformal coating, no matter how advanced, can compensate for contamination left on the board. Whether the application is in powertrain control, battery management, or advanced driver safety systems, the integrity of the coating—and the reliability of the system—depends on a clean foundation.

Designers must account for cleaning as a functional requirement. Test engineers must consider contamination when diagnosing performance issues. And process engineers must choose the right cleaning method to ensure a clean, dry, and residue-free PCBA before coating.

When the stakes include product recalls, warranty costs, or passenger safety, cutting corners on cleaning is not an option. Clean boards aren't simply good practice, they're essential for performance in today's harsh automotive environments.

Author Information:

Elizabeth Norwood is a Senior Chemist at MicroCare, LLC, which offers precision cleaning solutions. She has been in the industry for more than 25 years and holds a BS in Chemistry from the University of St. Joseph. Norwood researches, develops and tests cleaning-related products. She currently has one patent issued and two pending for her work.

For more information, visit www.microcare.com.