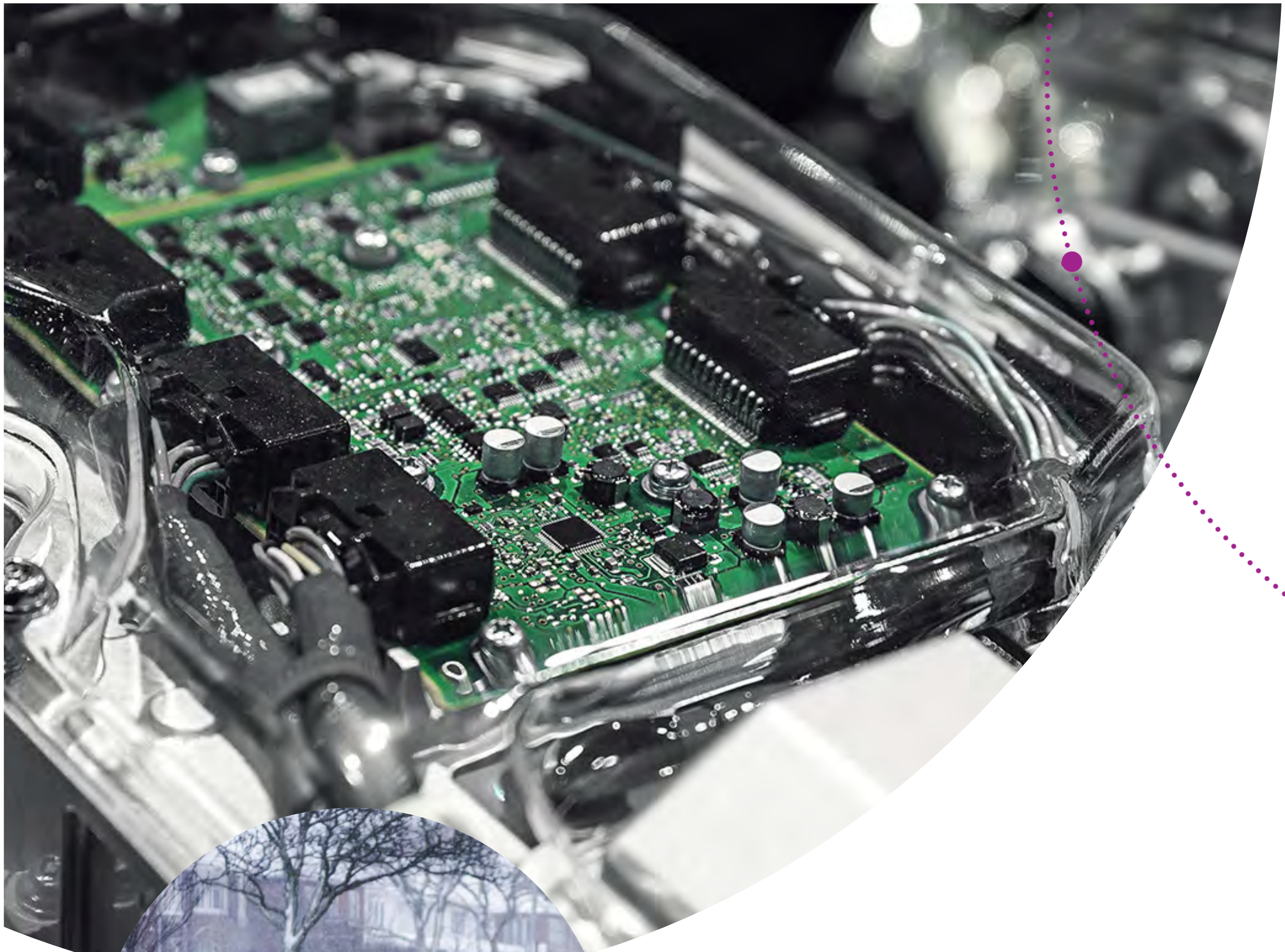
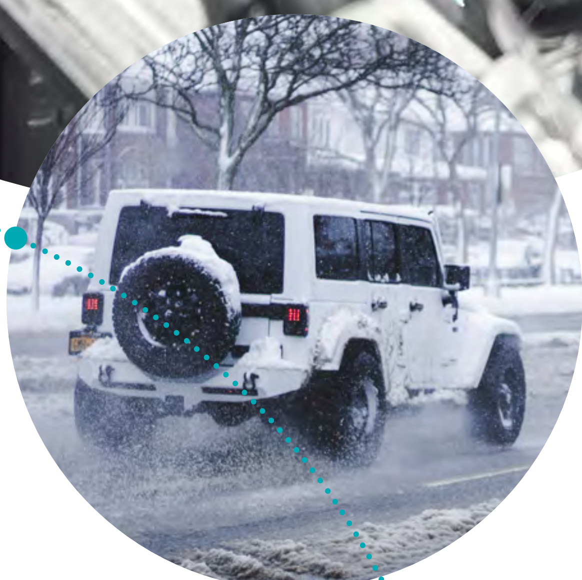




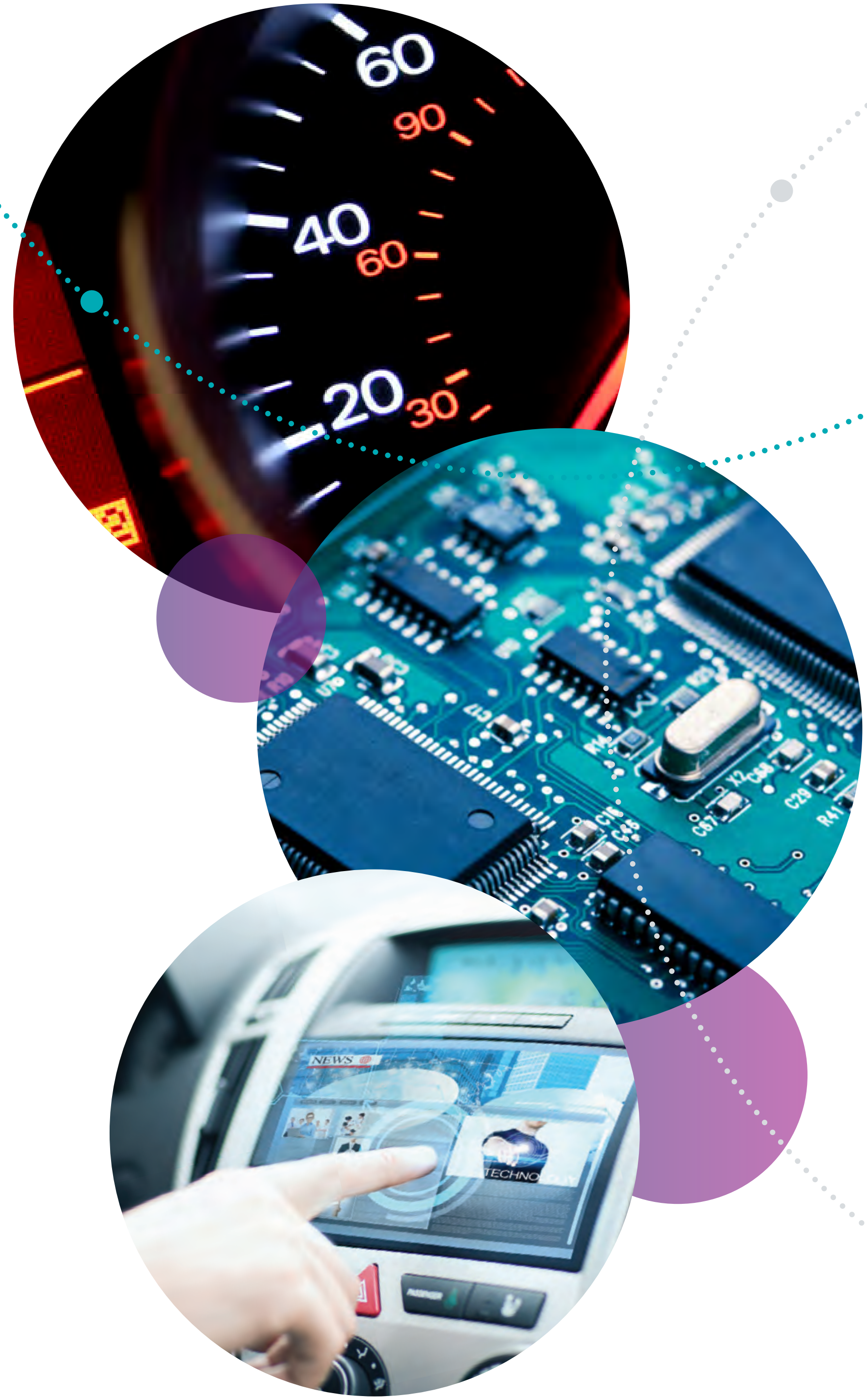
Protecting Printed Circuit Boards in Automotive Electronics

Contents

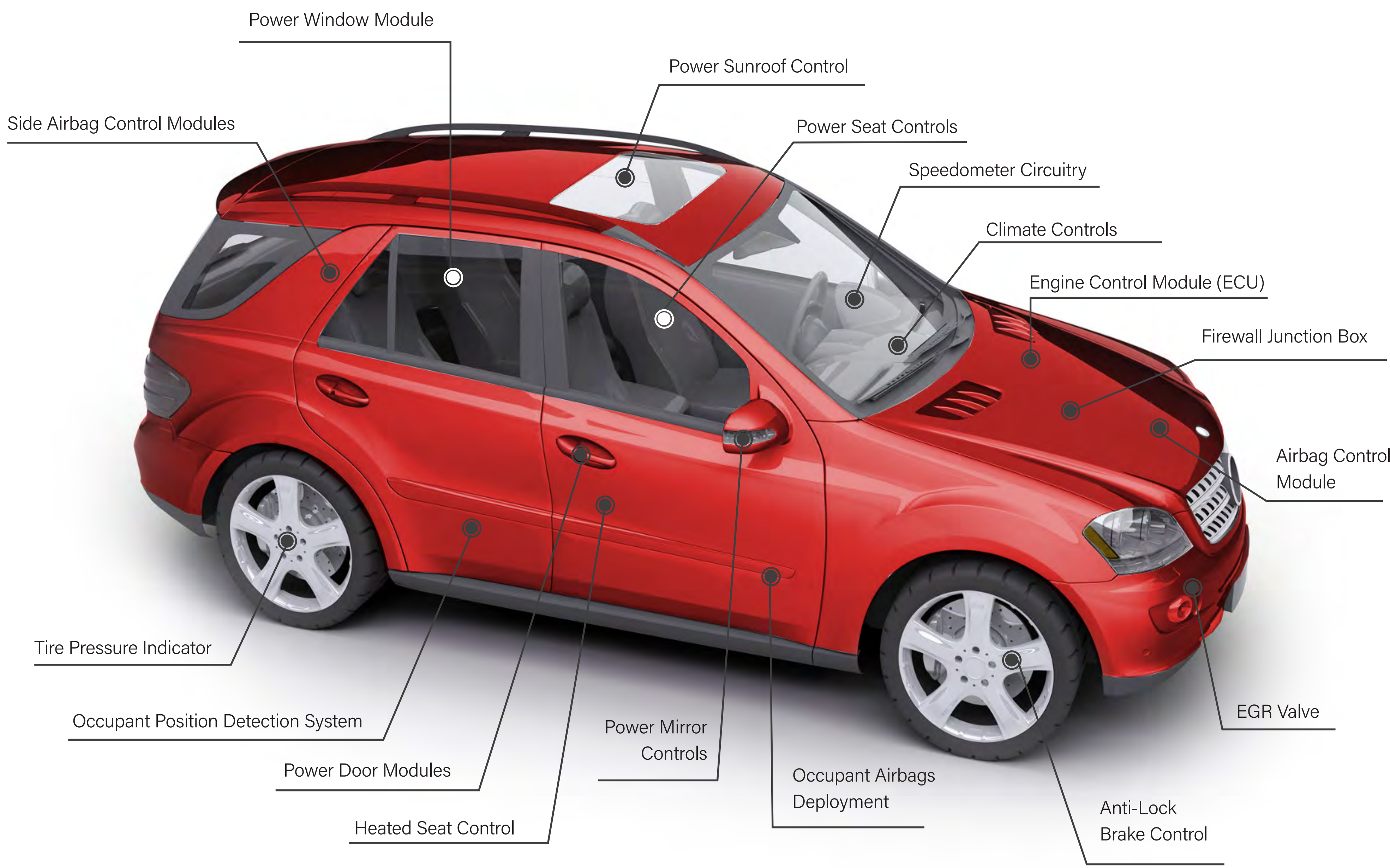
Introduction

The automotive electronics market has gained significant importance in recent years, as the industry, the culture and consumer expectations have evolved. Safety and regulatory requirements for vehicles have increased, manufacturers have new warranty requirements, and what used to be "luxury" features are now expected to come standard with a new car. Features like lane departure warning systems, rear-facing cameras, automated parking and other driver-assistance systems are becoming commonplace. Full "infotainment" systems, with software for navigation, music, communication and other applications, are gaining market traction, as well. The global electric vehicle market is also on the rise; and so is the pursuit of low cost, top performance protection of the electric vehicle battery system. Engineers are seeking innovative methods to protect the heart of the vehicle, the battery, from harsh environments.

With consumers expecting every new vehicle to be safe, comfortable and reliable, automotive manufacturers face the challenge of finding reliable, economical and high-performance circuit materials/ boards that minimize the effects of early field failures. Safety and infotainment systems depend greatly on the quality of the vehicle's electronics. How can the quality of air bag controls, fuel injection systems, suspension control, automatic transmissions, modules for power windows and doors, and engine control modules be guaranteed? This is one of the questions we answer in this e-book.



Places printed circuit boards may appear in an automobile



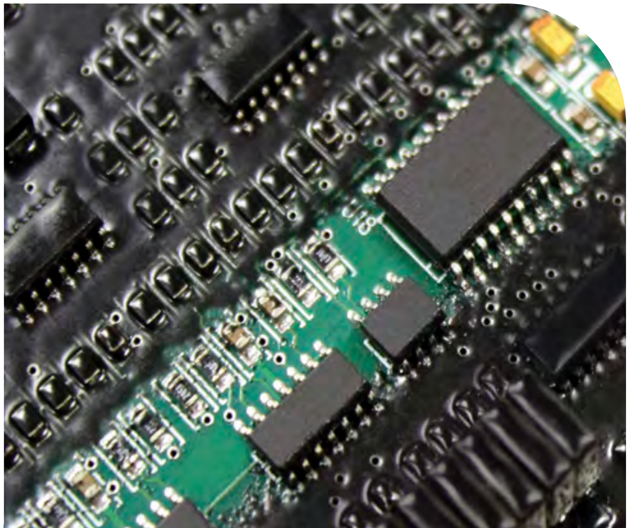
Materials Commonly Used to Protect Printed Circuit Boards

Engineers try to not only create well-tested software, but ruggedized hardware as well. In the automotive world, PCBs are placed wherever they fit best for a given vehicles system - which can be practically anywhere in the car. Sensors and circuit boards are found in places that can be exposed to everything from brake fluid to gasoline fumes, not to mention all the heat and vibration associated with an internal combustion engine. Properly protected PCBs guard the boards from elements that may damage and/or compromise the safety and operation of the vehicle.

Engineers have several material choices, including conformal coatings, potting materials, encapsulants, and gaskets, from which they can choose to improve the quality and durability of their automotive electronics.

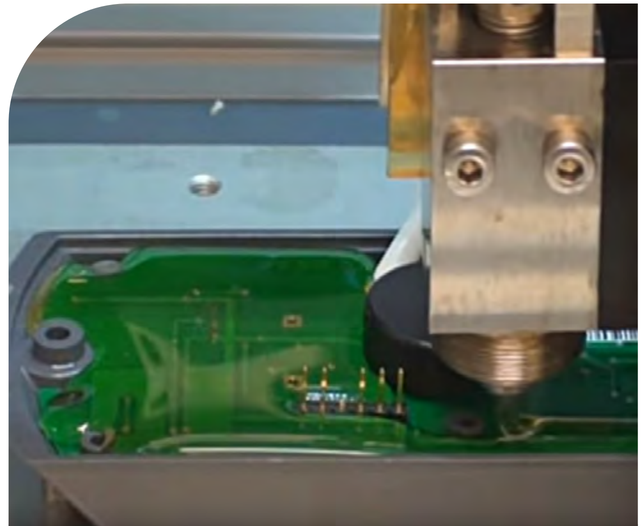
PCBs may be placed in an enclosure, or they can be potted with a resin. However, enclosing or potting takes up space and artificially limits the space available for the electronics. Potting entire PCBs also adds weight and cost- a no-no these days when weight-conscious engineers are seeking to shed every unnecessary ounce from a car.

Common Material Types



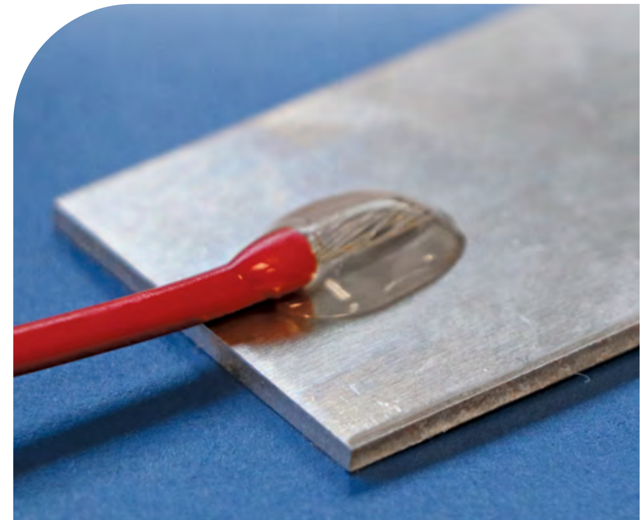
Conformal Coatings

Thin protective coatings that provide PCBs with protection from thermal shock, humidity, and corrosive elements like salt and sulfur. A variety of different types of conformal coatings are available in the market, including solvent-based, light-curable, and water-based.



Potting Materials

Potting is the process of partially or completely filling an enclosure with material with the goal of protecting the parts within from damaging elements. The most common types of potting compounds are light-curable, polyurethane, acrylic, epoxy, and silicone. They are an effective means of protecting automotive components from shock, vibration, and other damaging forces.



Encapsulants

Encapsulants seal out moisture and other corrosive elements for longer service life. They are used to protect sensors used in a variety of automotive electronics, including Advanced Driver-Assistance Systems (ADAS). Both one- and two-part technologies are available on the market.

Gaskets

Gaskets act as a barrier to prevent absorption or penetration of air, dust, noise, liquids, gaseous substances, or dirt for sound dampening, vibration dampening, moisture protection, chemical protection, and air sealing. Form-in-place gaskets have grown in popularity as they can easily conform to complex and intricate channels, on both vertical and horizontal surfaces.

Fortunately, conformal coatings are polymers that can be applied in thin layers to PCBs to protect and electrically insulate components from environmental stresses. They can be sprayed, brushed, flow-coated or dispensed by robots, and they take up very little space.

This brings us to another important point of this e-book; namely how and why conformal coatings work to protect PCBs. Conformal coatings are often applied to printed circuit boards to improve circuit reliability in harsh conditions. They are a protective layer of thin polymeric material that conforms to the contours of a printed circuit board to protect components. Light-cure conformal coatings are designed for process efficiency due to their speed of cure while minimizing the necessary production floor space. These coatings are engineered to protect circuit boards from humidity, dust, fungus, extreme temperatures and other contaminants. If left uncoated, leakage or corrosion can take place; and such delicate parts can be damaged.

They allow for smaller, lighter assemblies, since an enclosure is unnecessary. This makes it possible to fit more PCBs in the same space. Additionally, ability of conformal coatings to electrically insulate components can improve performance and permit a significant reduction in the space needed between conductors on a board.

Despite their thin application, coatings are very effective. Conformal coatings protect boards from mechanical and thermal stresses, humidity, corrosives and contaminants, such as salt, dirt, noxious gases and fungi.

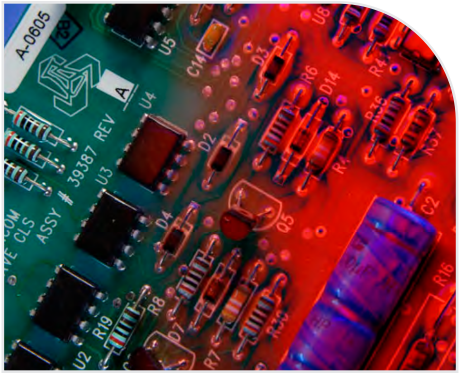
Tin whiskers are a common problem with today's lead-free PCB assemblies. Their growth is spurred by mechanical and thermal stresses, which are especially common in automotive settings. Conformal coatings can slow this growth, preventing arcing and short circuits. Coatings also increase mechanical support for components and improve the fatigue life of solder joints.

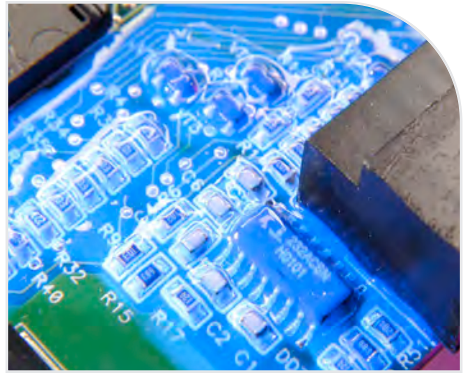
How Many Conformal Coating Choices Are There?

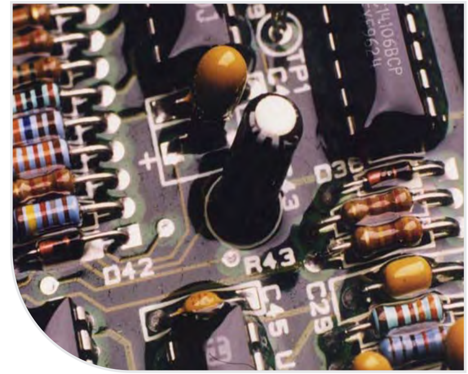
A variety of conformal coatings are available, including solvent-based formulas, silicones, two-part epoxies, and urethane acrylates. Light-cure coatings offer several advantages over other chemistries. Here's a quick description and comparison of each:

	ACRYLIC	EPOXY	LIGHT-CURE	PARAXYLYLENE
Main Features	General Purpose	Chemically Resistant	Fast, Tack-Free Cure	Great Coverage
Ease of Application	💧💧💧💧💧	💧💧💧	💧💧💧💧	💧
Drying or Curing Time	💧💧💧💧	💧	💧💧💧💧💧	💧
Chemical Resistance	💧	💧💧💧💧💧	💧💧💧💧💧	💧💧💧💧💧
Moisture Protection	💧💧💧💧💧	💧💧💧	💧💧💧💧💧	💧💧💧💧💧
Reworkability	💧💧💧💧💧	💧💧	💧💧	💧
Environmentally Friendly	Varies depending on chemistry	💧💧💧	💧💧💧💧💧	💧💧💧💧💧

NOTE: Each conformal coating type has hundreds of different formulations. This table is a general comparison and not applicable to every specific formulation.







	POLYURETHANE	SILICONE	SOLVENT BASED	SOLVENT-FREE 2K TECHNOLOGY	WATER BASED
	Chemically Resistant	High Temperature Resistance	Easy to Apply & Rework	Great Coverage with Exceptional Water and Humidity Protection	Manual Application Only
	💧💧💧💧💧	💧💧💧	💧💧💧💧💧	💧💧💧💧	💧💧
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	💧💧💧💧	💧💧💧	Varies depending on chemistry	💧💧💧💧💧	Varies depending on chemistry
	💧💧💧💧	💧💧💧💧	💧💧💧💧💧	💧💧💧💧💧	💧💧💧💧
	💧💧💧	💧💧💧	💧💧💧💧	💧💧💧	💧💧💧
	Varies depending on chemistry	💧💧💧💧💧	💧	💧💧💧💧💧	💧💧💧💧💧

Why Choose Light-Cure Conformal Coatings?

Light-cure conformal coatings cure on demand, in seconds, and are easier to automate as a total process than other types of coating because they can offer a fast tack-free cure. There is no need to stack and temporarily protect the boards and then have them undergo additional cure. Besides saving time, light-cure technology also saves space on the manufacturing floor and increases efficiency overall. There is no need for mixing, as with two-part epoxies. There's no need for explosion- proofing, as with solvent based coatings. And fewer steps and fewer operators are typically required for each processing step. In addition, no extra shipping charges are required, as may be the case with hazardous materials. Light-curable materials can be both silicone-free and solvent-free.

The curing mechanism is fairly simple. When light of the correct spectral output comes in contact with a light-curable material (LCM), the photo initiators in the material fragment to form free radicals, beginning the curing process. The free radicals begin to form polymer chains with the acrylates that comprise the LCM until all of the available radicals have attached and become a solid polymer.

6 REASONS TO CHOOSE LIGHT-CURABLE CONFORMAL COATINGS

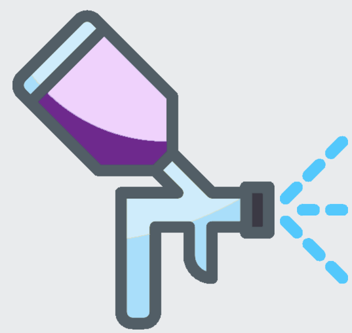
Fast, On-Demand Cures

One-Part Formulas
(No Mixing Required)

Solvent Free
(More Environmentally Friendly)

Smaller Process Footprint
(No racks or ovens)

Fluorescing Grades Available For Easy Inspection



Easy, Instant Application

Choosing the Correct Coating

When selecting a conformal coating, engineers should consider the design of their board and their entire assembly process. How will the coating be applied and cured? Does the design have shadow areas? These questions help narrow down the selection of conformal coatings so the most appropriate one can be chosen for the application.

Another very important question to consider is where the circuit board will ultimately be used. This information will help determine what conditions the PCB will be exposed to and ultimately, which testing should be conducted to ensure proper performance. Environmental and qualification tests can be used to simulate the conditions to which the PCBs and conformal coatings will be exposed. Performance testing against expected temperature extremes, moisture, abrasion, salt spray, vibration, chemicals, and other hazards will determine what conformal coating is optimal for a particular application.

The assembly's electrical performance requirements should also be considered. Thermal cycling testing exposes coated boards to alternating low and high temperatures to accelerate failures caused by temperature cycles or thermal shocks. This test is done under various conditions, yet -55°C to 125°C [-67°F to 257°F] is becoming a popular temperature range for automotive testing.

For applications that need higher chemical and abrasion resistance, engineers may want consider a light-cure conformal coating with a higher durometer. They are harder and particularly beneficial if especially thin coatings are desired. Softer, lower durometer conformal coatings reduce stress on components and offer the best thermal shock performance. For higher chemical resistance in softer coatings, a slightly thicker coating may be applied. Destructive testing is useful for determining what coating and application method are best for the boards being produced.

Industry Standards and Best Practices

Important automotive performance testing includes:

- High Temperature Flexibility
- Surface Corrosion Resistance - Flowers of Sulfur (FoS)
- Thermal Cyling (Typically -55°C to 125°C)
- Flame Resistance (UL 94V0)
- Temperature/Humidity - 85/85
- Salt Fog Resistance
- Fluorescence

Industry standards require materials to have the following certifications:

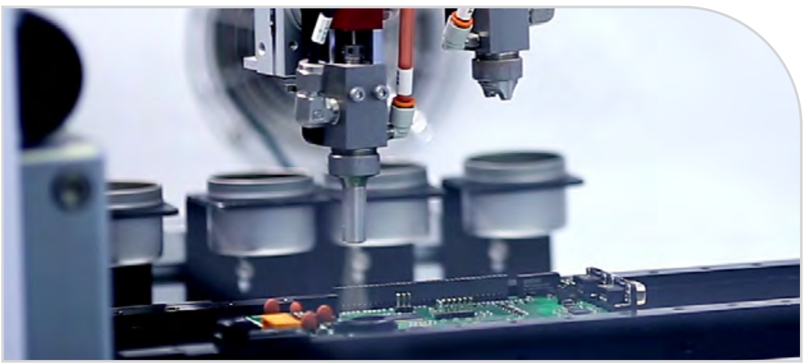
- IPC-CC-830
- MIL-1-46058C
- UL Flammability
- UL-746E

10 QUESTIONS YOU NEED TO ASK YOURSELF BEFORE CHOOSING A CONFORMAL COATING

1. What is the end environment for the board?
2. What requirements do you have for the coating? (UL, MIL, IPC)
3. Will you have shadow areas on your board?
4. Are you looking for secondary heat or moisture cure?
5. What are your testing requirements?
6. Which thickness are you looking for?
7. Will you be using a masking material in your process? If yes, which type?
8. How are you planning to apply the material?
9. How are you going to cure it?
10. What is your required time takt time to dispense, dwell, and cure?

Applying Conformal Coatings

There are several application methods for light-curable conformal coatings, including automated spray, curtain coating, and brushing. The infographics on the following pages discuss five of the methods in detail and give pros and cons of each. Regardless of how the coating is ultimately applied, care should be taken to ensure that all parts of the system are compatible with each other.



Special yellow lighting is available to prevent early curing from ambient light, though it is best if all parts of a dispensing system are entirely opaque.

Contamination is another issue. Conformal coatings are less effective if the boards are contaminated. In fact, the coating may seal in existing contaminants which can react to moisture and lead to deamination in that area over time. These contaminants can also prevent adhesion of the coating, typically by using a solvent or aqueous wash followed by the recommended drying cycle.

Clean boards should be handled with gloves so oils don't transfer from human hands to the PCBs. If necessary, clean boards can be stored in static-safe bags prior to coating.

If, for some reason, the boards cannot be cleaned, it is important to run tests to ensure that they will fulfill all end-use requirements with the existing level of contamination. Light-curable coatings have been developed with enhanced-wetting properties to limit the effects of board contaminants, such as no-clean flux.

Inspection is another issue to think about. All industry-approved conformal coatings fluoresce when exposed to black light. This helps operators see whether the coating has been applied completely and correctly. Laser measurement systems are also available to inspect boards for high-reliability applications.

METHOD 1: BRUSHING

The simplest form of application, this method uses a manual brush to apply the coating to the circuit board. It requires agility and care.

PROS

Very simple

Low start-up cost

Can protect against airborne foreign object debris

Minimal masking required

CONS

Difficult to control uniform thickness

Increases risk of bubbles and voids

Brush bristles can be a cause of foreign object debris

Brushes can push coating under parts

Not practical for high-volume production

Results can vary depending on operator experience

RECOMMENDED FOR

Prototypes

Touch-ups

Repairs

Small parts

Low-volume / high-mix production

METHOD 2: CURTAIN COATING

This method uses an uninterrupted curtain of coating material that falls onto the circuit board. It can be manual or automated.

PROS

- Even coverage
- Relatively inexpensive
- Material can be collected and reused
- Uncomplicated design

CONS

- Material can be affected by temperature and humidity
- Coating viscosity must be monitored
- Collection reservoir can become contaminated, causing defects
- Masking and preparation is required

RECOMMENDED FOR

- Complex shapes
- Smaller parts within assembly
- Low-volume production

METHOD 3: MANUAL SPRAY

The most popular and fastest method of applying conformal coatings. With the proper technique, this method can produce reliable and consistent results.

PROS

Simple system

Material viscosity is very stable

Reasonable cost

Can provide better coating on high-topography assemblies

Good for 3D assemblies (with proper training)

Easy to move the nozzle back and forth for better coverage

CONS

Hard to control the material thickness

Excess material is wasted or lost in the process

May require multiple coating/curing cycles

Masking is required

Harmful vapors need to be contained

Requires a disposable backing, which may cause foreign object debris or hazard-ous waste

RECOMMENDED FOR

Reworks

High-topography assemblies

Difficult 3D assemblies

METHOD 4: AUTOMATED SPRAY

Automated spray dispensing is ideal for complete topside surface coverage. Thickness will be affected by the feed system, nozzle speed, temperature of the material, and atomization pressure.

PROS

- Repeatable process
- System is not complicated to program
- Can be applied to in-line operations with curing

CONS

- May require masking
- Material waste/loss
- Excess over-spray and harmful vapors must be contained or exhausted
- Longer cycle time
- Requires slightly more maintenance
- Difficult to coat under components

RECOMMENDED FOR

- Complete topside surface coverage
- Medium- to low-volume production
- Projects where repeatability is required

METHOD 5: AUTOMATED SELECTIVE DISPENSE

While automated selective dispensing may be more expensive than automated spray, it is the fastest and most reliable method for applying conformal coatings.

PROS

Repeatable process for functional topside surface coverage

Eliminates the need for masking

Limited material loss

Shortened cycle time

Can be applied to in-line operations with curing

CONS

Not ideal for side coverage

Higher systems cost than spray application

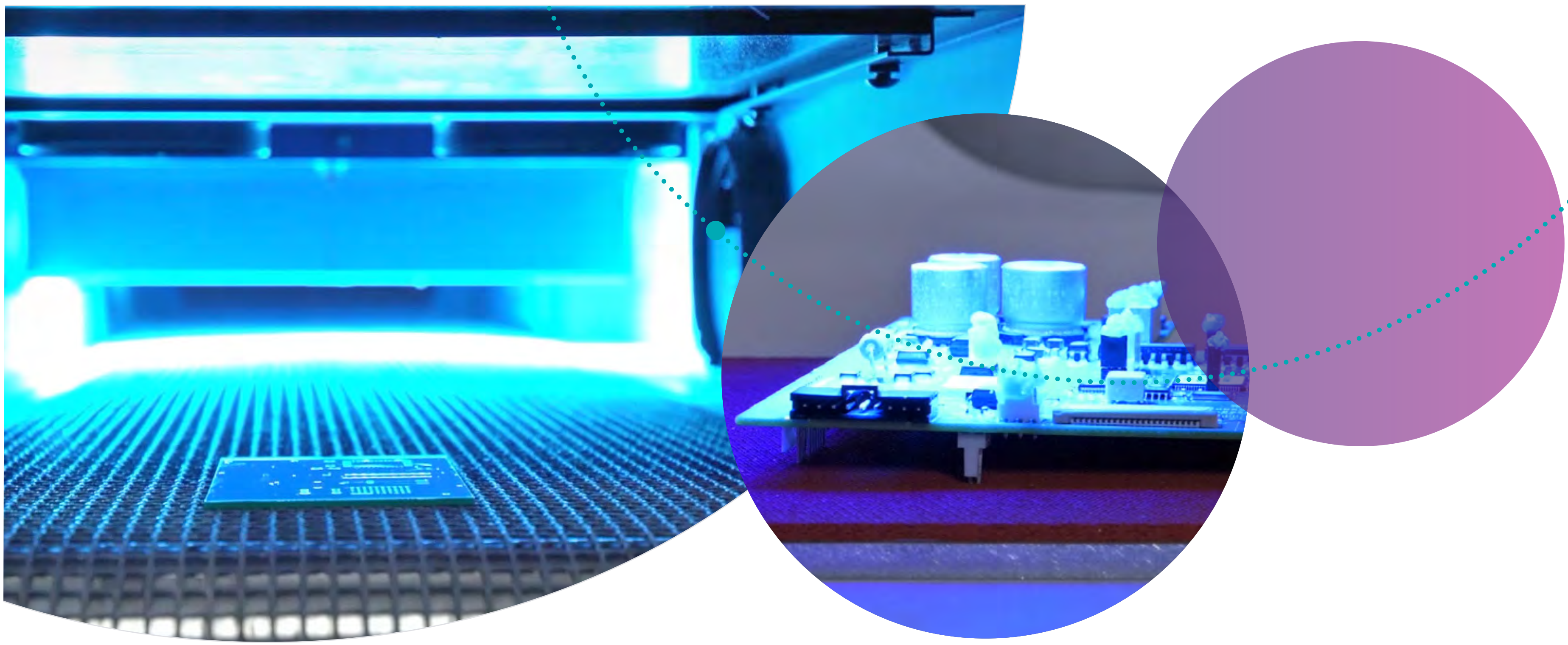
System more complicated to program than spray applications

RECOMMENDED FOR

Moderate to high-volume applications

Functional topside surface coverage

Projects where repeatability is required



Curing Processes for Light-Curable Conformal Coatings

For complete and reliable curing of light-curable materials, it's important to select a light source with the optimal intensity and spectral output for the photoinitiators in the light-curable material.

Typically, light-curable conformal coatings absorb light in the UV-A and blue visible-light range. Many light sources are available for curing conformal coatings; the most common curing setups are automated conveyors and bench-top flood systems. Spot curing systems are also available but are recommended only for rework and for small curing areas. For a successful curing process, it is important to ensure all parts of the system are compatible with each other.

Light intensity – measured in milliwatts per square centimeter - is the amount of energy at a given wavelength that reaches the coating surface over a given time is known as the does, measured in millijoules per square centimeter. In brief, higher-intensity lamps cure faster, with all variables held constant, but too much intensity can damage the materials and parts. Hence, it is best to confirm with your conformal coatings partner what the optimal intensity for your application is.

As with any light-curable materials, it is critical to use a radiometer to ensure the light source is continuing to emit at sufficient intensity for complete and reliable curing of the conformal coating.

Curing in Shadow Areas

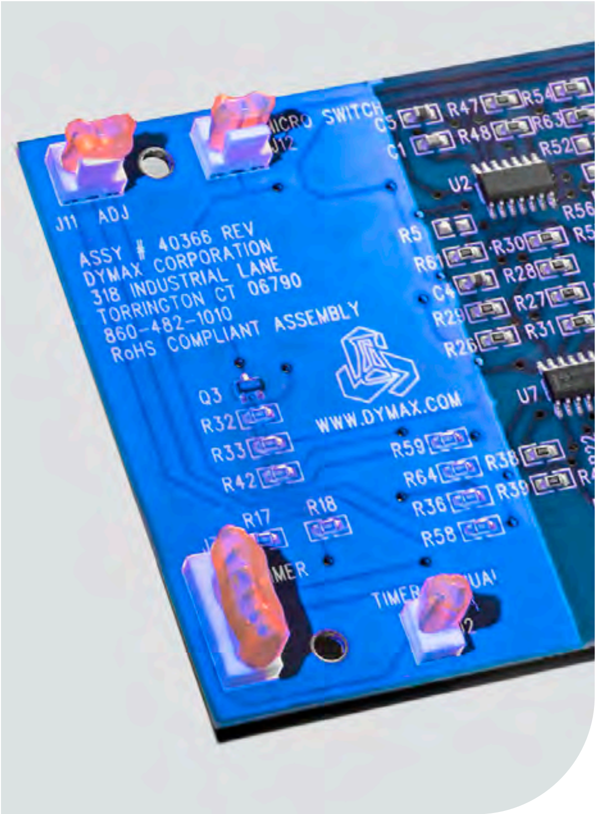
For light-curable conformal coatings to cure properly, they must be exposed to a sufficient amount of light energy. Some circuit boards have shadow areas where light cannot reach directly, leaving coatings in that area uncured. To prevent this, light-curable coatings can either be blocked from entering those areas or they can be cured with a secondary mechanism.

Preventing Coating from Entering Shadow Areas

If the coatings do not flow into shadow areas, then there is no need for a secondary cure. Smaller low-offset surface-mount components are significantly less likely to allow coatings to flow beneath them. Selective automated application of medium-to high-viscosity coatings is also an option. Another option is to mask specific areas of PCB to ensure the coatings don't flow into areas like connectors, through-holes, and other keep-out areas on the board. While various methods are available, some can be labor-intensive, so minimizing or eliminating the need to mask is desirable.

Secondary Cure Mechanisms

Dual or Multi-Cure® coatings can be used to cure material that flows into shadow areas. Besides UV light, these materials cure with heat or by reacting with ambient moisture.



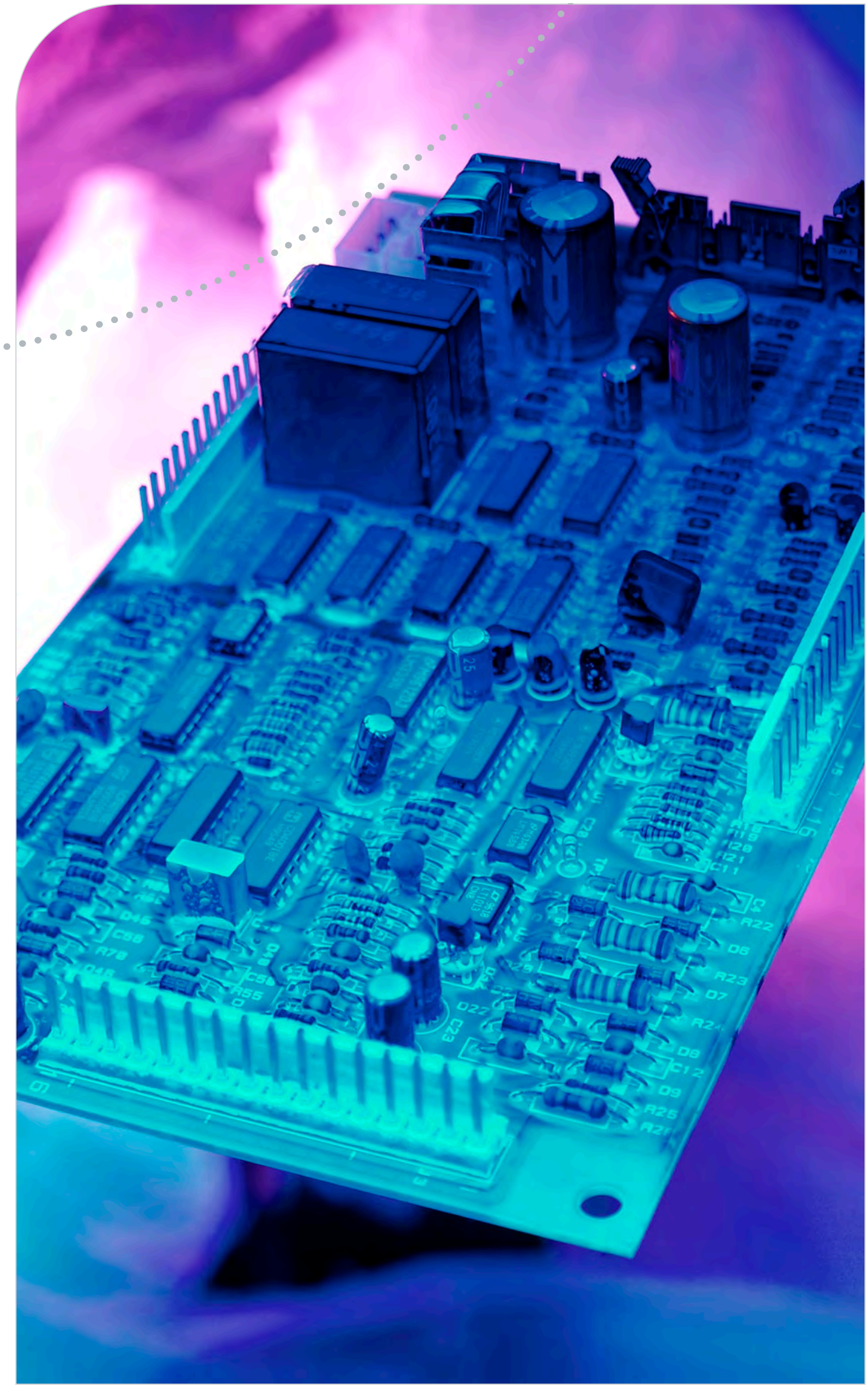
[Maskants](#) can be used to prevent coatings from covering or flowing under components

Conclusion

Automotive manufacturers face the challenge of finding reliable, economical and high-performance circuit materials that minimize the effects of early field failures. And now they face a greater challenge with electronic vehicle battery systems as e-mobility designs of full electric and hybrid electric vehicles continues to gain traction. The battery is the heart of an electric vehicle and must maintain performance under drastic temperature changes and corrosive elements like salt and sulfur, as well as moisture, vibration, and shock.

In conclusion, properly protected PCBs and hybrid/electric vehicle batteries will ensure top performance, functionality and long service life. Whether your component needs to be bonded, sealed, potted or coated, the right material should offer protection without affecting the efficiency of the manufacturing process.

More than anything, a technical consultation with your manufacturing partner is advisable to help you build a process, compare products and finalize your selection.



Want to Learn More?

Visit the dymax.com resource center for more information on light-curable maskants.

A wide variety of educational materials are available, including:

- Comprehensive guides
- Infographics
- White papers
- Webinars
- Articles
- Application case histories
- Videos
- And more!

If you have questions or would like to discuss an application, our Application Engineering team can help. Contact them today.

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