

Conformal Coating for Variable Speed Drives

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Abstract

The demand for robust drives and high reliability continues to increase – customers expect drives to operate for at least five years without failures in all locations, including harsh environments. How can contemporary drives be designed to address harsh environments, like aggressive gases, humidity and contamination, and at the same time maintain reliability?

As drives become smaller and more compact, internal cooling fans are essential. To cool the drive, the fans force ambient air over electrical components at a relatively high velocity. While this helps keep the drive cool, it also often results in the acceleration of particle accumulation across the connections of fine pitched components. The problem is greatly compounded if even a small amount of moisture is present, which promotes electrical failure.

One solution is to use conformal coating on the Printed Circuit Boards (PCBs), which protects components with micro lead spacings. These PCBs also include masked areas for terminal blocks and other connection means that cannot contain any coating. These masked areas are vulnerable and should be protected with enclosures.

The primary feature of a coated PCB is for the protection of the micro lead components that are vulnerable to dust and moisture build up, which can result in conductive paths.

For increased levels of protection, and to address the uncoated portions of PCBs and other components, an appropriate enclosure type should be employed in addition to conformal coating.

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Variability in Levels of Conformal Coating

Analysis of random samples shows that the amount of coating coverage is not consistent among manufacturers. Using ultraviolet light, Figures 1-3 illustrate in some cases, the majority of a PCB is covered, and in others, only select areas are coated. In nearly all cases, there are PCB areas that cannot be coated, such as connectors. Also, the uniformity varies. On some products, the coating gets applied manually, producing inconsistent thickness, and sometimes with significant voids (bubbles).

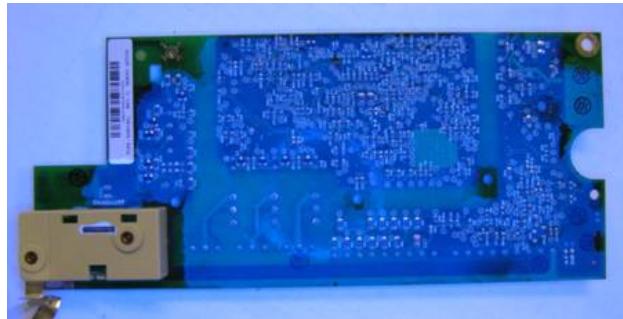


Figure 1: Majority Coverage



Figure 2: Minimal Coverage



Figure 3: Selective Coverage

What standards are used for environmental protection levels?

Traditionally, the IEC and NEMA enclosure standards were used for drive-level protection. Some drive manufacturers state compliance with environmental standards, such as IEC 60721-3-3, and have statements such as “PCB protection to IEC 60721-3-3” along with the appropriate category level.

What is the intent of IEC Standard 60721-3-X

This standard classifies environmental parameters for products deployed in weather-protected locations during periods of uptime, downtime, maintenance and repair.

There are three parts to this standard.

- IEC 60721-3- 1 Storage Environmental Conditions
- IEC 60721-3- 2 Transportation Environmental Conditions
- IEC 60721-3- 3 Operation Environmental Conditions

This paper addresses the chemical and mechanical values specified in IEC 60721-3- 3 Operation Environmental Conditions. The levels of chemically and mechanically active substances and classes defined in this standard are illustrated in Figures 4 and 5.

Table 4 – Classification of chemically active substances

Environmental parameter	Unit ¹⁾	Class ²⁾					
		3C1R Maximum value	3C1L Maximum value	3C1 Maximum value	3C2 Mean value	3C3 ³⁾ Mean value	3C4 ³⁾ Mean value
a) Sea salts	None	No	No	No ⁴⁾	Salt mist	Salt mist	Salt mist
b) Sulphur dioxide	mg/m ³ cm ³ /m ³	0,1 0,037	0,1 0,037	0,1 0,037	1,0 0,37	5,0 1,95	10 3,7
c) Hydrogen sulphide	mg/m ³ cm ³ /m ³	0,0015 0,001	0,0015 0,0071	0,001 0,071	0,5 0,36	3,0 2,1	10 7,1
d) Chlorine	mg/m ³ cm ³ /m ³	0,001 0,00034	0,001 0,0034	0,001 0,034	0,3 0,1	1,0 0,34	3,0 0,2
e) Hydrogen chloride	mg/m ³ cm ³ /m ³	0,001 0,00066	0,001 0,0066	0,001 0,0066	0,5 0,33	1,0 0,66	5,0 3,3
f) Hydrogen fluoride	mg/m ³ cm ³ /m ³	0,001 0,0012	0,0003 0,0036	0,0003 0,012	0,03 0,036	2,0 0,12	2,0 2,4
g) Ammonia	mg/m ³ cm ³ /m ³	0,03 0,042	0,03 0,42	0,03 0,42	1,0 1,4	3,0 4,2	35 14
h) Ozone	mg/m ³ cm ³ /m ³	0,004 0,002	0,004 0,005	0,004 0,005	0,05 0,05	0,1 0,05	2,0 0,15
i) Nitrogen oxides (expressed in equivalent values of nitrogen dioxide)	mg/m ³ cm ³ /m ³	0,01 0,005	0,01 0,052	0,01 0,052	1,0 0,52	3,0 1,56	20 4,68
							5,2 5,2
							10,4 10,4

¹⁾ The values given in cm³/m³ have been calculated from the values given in mg/m³ and refer to a temperature of 20 °C and a pressure of 101,3 kPa. The table uses rounded values.
²⁾ Mean values are expected long-term values. Maximum values are limit or peak values, occurring over a period of time of not more than 30 min per day.
³⁾ It is not mandatory to consider each of classes 3C3 and 3C4 as a requirement for the combined effect of all parameters stated. If applicable, values of single parameters may be selected from these classes. In this case the severities of class 3C2 are valid for all parameters not especially named.
⁴⁾ Salt mist may be present in sheltered locations of coastal areas and in offshore sites.

Figure 4: Chemical Substances

Table 5 – Classification of mechanically active substances

Environmental parameter	Unit	Class			
		381	382	383	384
a) Sand	mg/m ³	None	30	300	3 000
b) Dust (suspension)	mg/m ³	0,01	0,2	0,4	4,0
c) Dust (sedimentation)	mg/(m ² · h)	0,4	1,5	15	40

Figure 5: Mechanical Substances

The limitation of this standard is it does not account for long-term material degradation, which can occur even after the substance exposure has ceased.

Consider the requirements for a NEMA 4X enclosure. The specified limits in Standard NEMA 250 clearly state 600 hours of salt fog and 1200 hours sulfur dioxide are required.

5.9.1 600 Hour Salt Spray Test

Comparative tests shall be conducted in accordance with 5.8, except the test time shall be 600 hrs.

5.8.2 Salt Solution

The salt solution shall be prepared by dissolving 5 parts by weight of salt in 95 parts by weight of either distilled water or water containing not more than 200 parts per million of total solids. The salt shall be sodium chloride that is substantially free of nickel and copper and that contains, when dry, not more than 0.1 percent of sodium iodide and not more than 0.3 percent of total impurities.

5.9.3 1200 Hour Moist Carbon Dioxide, Sulfur Dioxide—Air Test

Enclosures, or representative samples, shall be tested and evaluated in accordance with UL 1332.

If IEC 60721-3-3 is only applied to the PCB covered areas – and not the entire drive – the unprotected areas, such as the connections, terminations and exposed magnetics, may not survive these exposure levels over time.

Case study:

Figure 6 shows a PCB with conformal coating that was subjected to four weeks of salty air mist at an installation sight near the Pacific Ocean. Although the conformal coated areas withstood the elements, the wire insulation absorbed the substance, allowing it to travel down the wire and attack the internal PCB connection.

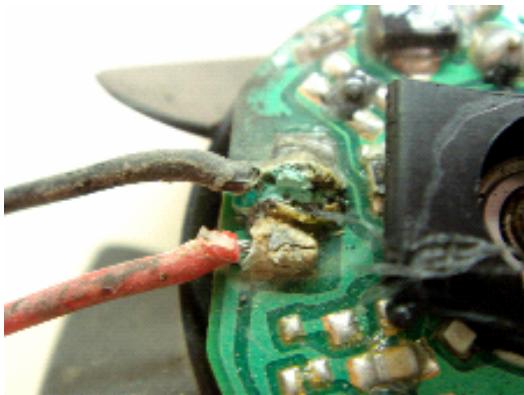


Figure 6: Coated PCB wire contamination

Conclusion

A PCB with conformal coating protects components with micro lead spacings which are otherwise vulnerable to dust and moisture build up. Without coating, unintentional conductive paths can be formed, leading to circuit failure. While this approach provides more protection than an uncoated PCB, other factors must be considered in the overall application of a drive.

As noted earlier, the masked areas of a PCB (areas that cannot be coated) are still vulnerable to contaminants. In addition, non-PCB components, such as inductors, fans, transformers, and power semiconductors, are not necessarily protected, and may become weak links within a design, resulting in product failure as a function of contamination.

For increased levels of protection, and to improve reliability, an approved enclosure should be employed in addition to the conformal coating.

ACKNOWLEDGEMENT

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