

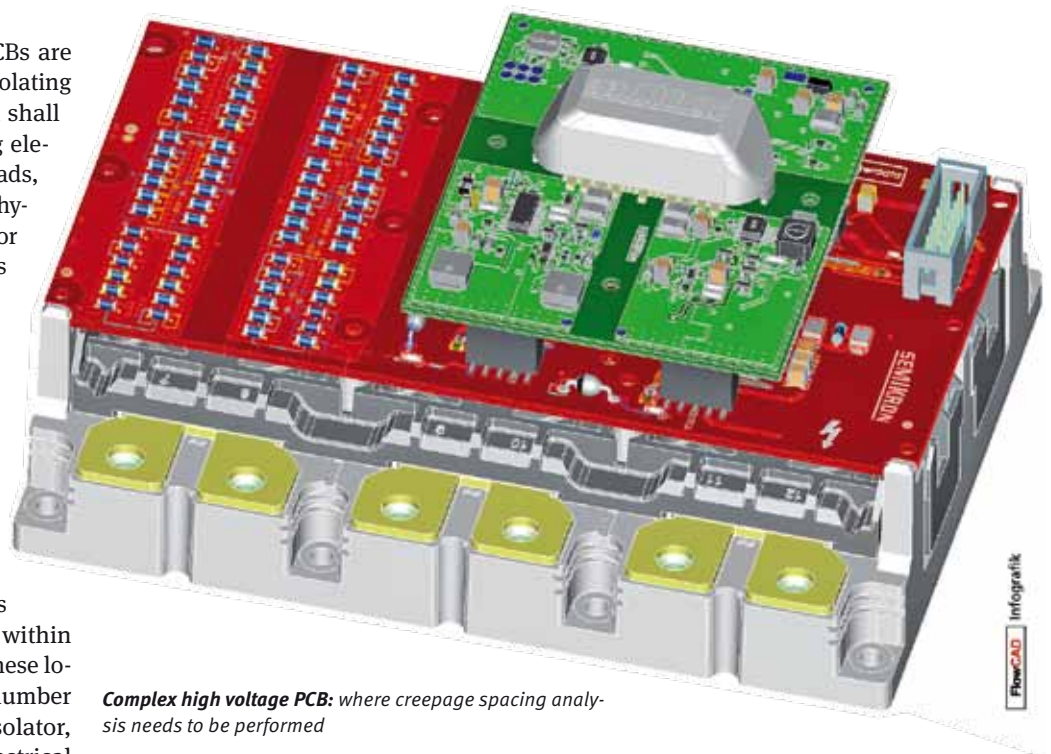
# The Great Escape – Current Gone Elsewhere

*Creepage current a serious problem to be controlled in power electronics on printed circuit boards. False manual measurements risk life of humans.*

DIRK MÜLLER \*, PETER MAUER \*\*

Common knowledge is that PCBs are made out of conducting and isolating material and that the current shall only use the designated conducting elements like component pins, tracks, pads, vias and copper planes. But the real physical world offers some exceptions for the current, which a PCB designer has to take into account too.

While implementing high voltages on printed circuit boards a partial electrical discharge may happen, where current will flow through the isolating material (FR4) or through the isolating air. Partial discharges happen where isolating material is inhomogeneous and the electrical field will be changed at these locations. These inhomogeneous locations can be gas bubbles captured within FR4 carrier or pollution in the air. These locations have a lower dielectrical number compared with the surrounding isolator, which causes an increase of the electrical field intensity. Discontinuities of the isolators have a much lower dielectrical strength so the voltage will break through and a current will flow through the isolator. These break-through voltages are specified for FR4 and Prepreg by its guaranteed dielectrical strength. So the designer just has to take care of the correct specification for the isolator and can consider them as an ideal isolator for the creepage analysis.



**Complex high voltage PCB:** where creepage spacing analysis needs to be performed

But creepage currents are following the same physical effect. Due to local dirt or dust on the surface of the isolator a local break trough can happen through the isolating air. This leakage current is flowing on the surface of the isolator where the pollution is located. The isolator's specification is described by the dielectrical strength, but the dielectrical strength on its surface can be very different.

## Working Voltage Can Be 1000 Volts And Higher

A longer creepage distance as the required air gap can have a lower dielectrical strength and the current will break through on a longer way, but with the least resistance. The reason for this can be pollution like dust, oil, or water on the surface of the printed circuit board. The pollution may happen in the factory during the PCB production pro-

cess or during the usage in the field by the end user.

On isolating areas between two conducting electrical circuits minimal creepage spacing is required. This creepage spacing might be larger than the normal spacing rules designed for manufacturing purpose. The creepage spacing has also to cover a 3D path around cutouts on the PCB surface. Especially in power electronics voltages where working voltages can be 1000 volts and more between conducting elements on a printed circuit board safety standards need to be met. This difference in electric potential is enough to let current flow across a polluted surface. To assure the minimal spacing is respected a design rule check has to measure all possible lengths on the surfaces between two conductors, through holes and in between diffe-



\* Dirk Müller  
...is General Manager FlowCAD EDA-Software, Feldkirchen.



\*\* Peter Mauer  
...is Manager Electronics Design Semikron, Nürnberg.

rent layers in a three dimensional environment.

All international safety standards for creepage analysis assume that isolators are ideal and there is no way for the current to break through the isolator material itself (the break through current for isolator materials have to be documented separately). It is considered that a potential creepage current will not only flow on the surface of the printed circuit board, but also on the surface of inner layers of multilayer printed circuit boards. It is possible, that a leakage current will enter the printed circuit board from the sides or open areas at cut outs like drills or milling areas. All possible shortest paths between electrical elements have to be measured on the surfaces and sides of the board to ensure the safety standards.

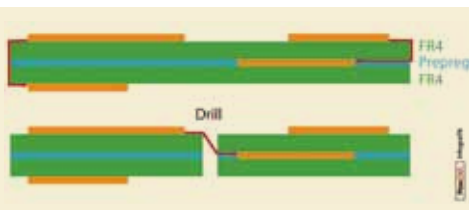
### 3D - Creepage Analysis and International Standards

There are various international safety standards for creepage current in place. Many standards evolved historically from different sources and are inconsistent with each other and sometimes confusing. Some standards are: VDE 0109, VDE 110, DIN EN 60664, DIN EN 50124, IEC 62497 UL 508 und CSA-C22.2 No.14.

National and international committees and government agencies define very detailed documents on this topic, but they are not based on the same physical principals. But all standards have in common, that you have to watch out for at least these four parameters: working voltage, pollution degree, overvoltage category and specifications of isolator material.

### Limits of Traditional Printed Circuit Board Tools

Independent of how the standard calculates the various requirements, at the end a set of minimal spacing rules in 3D is in common with all standards. The minimal spacing on the printed circuit board depends on the working voltage and the degree of pollution which requires certain spacing to avoid a break trough. Different values for minimal



**Open doors:** Leakage currents may enter the PCB at open sides or at drills

**BEST  
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## Software discovers Creepage Violation

The new creepage module of Nextra's 3D printed circuit board software discovers and displays creepage violations in printed circuit board layout design data. Based on settings for design rules which describe degrees of pollution the allowed spacing will be measured in three dimensions. Design data for printed circuit boards can be imported from most of the printed circuit board layout systems.

### No Manual Measurements

Creepage spacing measurements for approval by the authorities are made today manually. This is a error prone and time consuming process in printed circuit design. No such specialized software was available until today to measure the creepage paths in respect of electrical pollution classes for printed circuit boards.

spacing depending on overvoltage categories are described by formulas or in complex tables.

Today's PCB layout software tools include design rule checks which are required to create regular layouts. These rules are i.e. minimal and maximal length of tracks or spacing rules for manufacturing purposes. If rules are set the auto router will respect them and if there is a violation the Design Rule Check will highlight these errors automatically. But all these design rules in traditional tools are based on two dimensions and will only perform the check on each layer on its own. 3D spacing measurements across different layers are not performed.

Traditional layout systems support design rules between individual nets and net classes, but they will also not differentiate between electrical circuits as they are required by the safety organizations. So these 2D spacing rules can be used only to certain extend but have several limits and offer finally no guarantee.

In two dimensional design tools you can specify the stack up with various heights of FR4 but there is no way to define, how the stack up is build up with prepreg or separate

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## Energy Harvesting

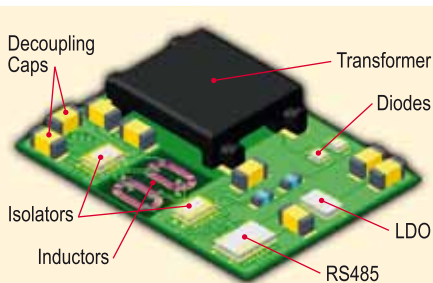
- LTC3108 Thermal (Peltier)
- LTC3588-1 Vibration (Piezo)
- LT3652 Photovoltaic (Solar)
- LTC4070 Shunt Battery Charger



Energy harvesting is the way to convert energy from Vibration (Piezo), Photo-Voltaic (Solar) and Thermal (TEC, TEG Thermopiles, Thermocouples) sources. Various energy sources that were not useful as power sources for electronic sensors can be used now.

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### µModule™ Pros

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## Creepage Analysis in 3D Context

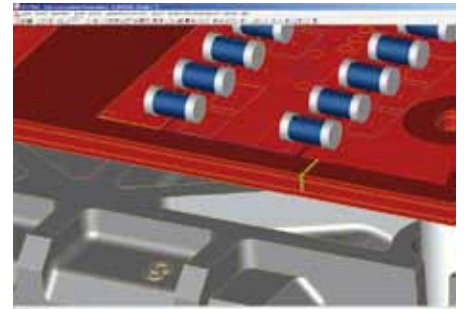
Nextra, a 3D PCB Design software tool, enables the user to import design data created in traditional PCB tools like Cadence, OrCAD, Mentor Graphics or Zuken and perform a creepage analysis. Two dimensional data will be imported and missing information for prepreg and isolators will be added. After that a creepage analysis can be performed using a 3D context and measure all shortest current paths on surfaces outside and inside of the PCB across multiple layer.

## The Software will Consider The Shortest Path

The creepage analysis module can address the issues required for this type of analysis. Several nets can be grouped to groups of electrical circuits which will be measured against specific nets required by the standards. This grouping can be assigned manually after import or automatically during import, if the design data contains properties. Nextra will consider for calculating the shortest path the board outline as well as the drill holes and millings. Millings are made often to increase the spacing between two electrical circuits. But sometimes an inserted milling to solve one problem will offer a shorter path for some other nets on other layers as a side effect and generate another error.

## A Time Consuming And Error Prone Process

Certification procedures at official agencies like IEC or TÜV will measure all spacing manually in the documentation. This is a time consuming and error prone process. An automated process with specialized software will discover errors faster and more predic-



**Zoomed in:** display of creepage violations (green) in 3D context

table for the complete board. After reading in the design data through a dialog menu for creepage measurements and assigning the grouping of electrical circuits, the user can decide if he only wants to perform measurements on single nets or if a complete check (all groups against all groups) shall be performed. It is also possible to select only a certain area of the PCB where checks shall be performed with different working voltages or pollution degrees. These area specific rules can be imported via properties in the design data.

## Perfect Match Even On The Most Complex Structures

The results of the creepage design rule check is a table which lists the nets or electrical groups between rule violations was found. A 3D view of the PCB is provided as well, which will show the actual shortest path for better explanation. 3D paths can be complex to describe when they will follow rounded surfaces or go across layers. With cross probing between the table and the 3D view errors can be documented and described easily.

Complex paths of the minimal spacing which follow diagonal path on the surface of a drill cannot be manually measured and the exact value can manually not be determined. This software will measure even on the most complex structures the shortest path while considering the different pollution degrees on different layers. Life threatening safety violations can be analyzed by virtual rotation in a 3D representation. //KU

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### InfoClick

- Details of NEXTRA 3D ECAD System
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## What is creepage?

Creepage on a printed circuit board is a leakage current which does not flow within the conducting material on the printed circuit board, but on top of the isolator's surface. This is possible due to a polluted surface with dust or dirt i.e. oil, particles, or water. Undiscovered creepage risk life of humans.

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setron GmbH

Friedrich-Seele-Straße 3a  
38122 Braunschweig  
Tel: +49 531 8098-0  
[linear@setron.de](mailto:linear@setron.de)