Power Electronics
In the coming years, power electronics solutions will play a key role in providing results and mastering the challenges presented by electromobility, energy production and energy distribution. Of all circuit board manufacturers, SCHWEIZER offers the most comprehensive range of solutions. In the automotive industry, SCHWEIZER’s printed circuit boards are already used today to conduct currents of up to 1,200 amperes. Numerous solutions are available for the best heat dissipation or passive cooling, including systems with active cooling.

**Overview of SCHWEIZER’s solutions:**

<table>
<thead>
<tr>
<th>Thick Copper Board</th>
<th>if very much current needs to be conducted over the whole printed circuit board</th>
<th>page 3</th>
</tr>
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<td>Wirelaid™</td>
<td>the wire-written printed circuit board for cost-optimised high current applications</td>
<td>page 4</td>
</tr>
<tr>
<td>Power Combi Board</td>
<td>high current and signal processing are combined for cost-optimised use</td>
<td>page 5</td>
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<tr>
<td>IMS Board</td>
<td>for maximum heat dissipation</td>
<td>page 6</td>
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<tr>
<td>Inlay Board</td>
<td>for maximum current and heat dissipation</td>
<td>page 7</td>
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<td>Thermal vias</td>
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</table>

For instance, the development of inverters is significantly driven by following conditions:

- High conversion efficiency over the entire input voltage range
- Inverters with higher performances
- Inverters with small dimensions
- Higher clock frequency
- High availability or long life (MTTF - Mean Time To Failure)
- Low manufacturing costs

A suitable cooling concept and the optimisation of the current carrying capacity have a considerable effect on the mentioned variables. For example, a long usage at operating temperatures > 50°C can result in power reduction of the inverter. Moreover, components and soldering points are burdened more heavily and can cause premature failures during the intended long-term use.

Since PV systems are preferably used in countries with high outdoor temperatures, additional temperature influences burden the devices.

Although at first sight the approach of using the active cooling system seems to be effective, but, on the other hand, the power consumption reduces the overall efficiency. Furthermore, additional devices create more susceptibility to failure, which reduces MTTF and increases production costs.

Therefore, researchers are looking for solutions to achieve the best possible conditions with a passive cooling concept. The following paper describes what the printed circuit board can contribute to it.

Inverters are usually equipped with cooling elements, which are clearly visible. However, the question arises as to how the heat of the components effectively reaches the cooling element. Special designs of the printed circuit board can help here. The rapid spreading of the heat is also crucial for the long life of the inverter, especially in the area of the capacitors, in order to avoid hot spots.
The printed circuit board solutions:
- Thick Copper Boards
- Wirelaid
- Combi Board
- Inlay Board
+ Thermal vias

Thick copper technology

This technology has been established for many years on the market and is manufactured in large production series. In the printed circuit board industry, thick copper stands for thickness from > 70 to 400 µm.
Ideally, the thick copper layers are placed inside the printed circuit board. For manufacturing reasons, the copper thickness on outer layers is limited and is usually 105 µm maximum.

<table>
<thead>
<tr>
<th></th>
<th>Thick Copper</th>
<th>105µ</th>
<th>210µ</th>
<th>400µ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Layer</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Outer Layer</td>
<td>X</td>
<td>(X)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Up to 4 inner layers with a thickness of 400 µm Cu can be used to achieve a current-carrying capacity of several hundred amperes. Additional bore holes offer many opportunities for heat dissipation.

Advantages of the thick copper technology:
- Use of standard components
- Common technology with high market penetration
Wirelaid™
– the low-cost solution for high currents and logic on one board

An alternative to thick copper technology is, among other technologies, the patented wirelaid technology by Jumatech, which has been used by SCHWEIZER for many years. In this technology, discreet wires are placed inside the printed circuit board. This allows partial and exact enlarging of the cross-section of the circuit path for managing high currents. Silverplated copper wires inside the board create additional connections for conducting high currents. The complex etching of the copper layer with a thickness of up to 400 µm is not required and the SMT-compliant outer layer remains free for signal wiring. Thus, it is also possible to place the control electronics and the power electronics together on one board or even on one layer.

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100µm</td>
<td>300µm</td>
</tr>
<tr>
<td></td>
<td>250µm x 800µm</td>
<td>350µm x 1400µm</td>
</tr>
</tbody>
</table>

In cooperation with
Power Combi Board

The basic idea of the Combi Board is to apply thick copper only in necessary areas for the most effective use of the expensive basic material. The Combi Board has an inner layer with both thick copper areas for high current applications and standard copper thickness for the signal routing.

- The Combi Board allows thick copper and fine circuit board technology of down to a minimum of 100 µm to be placed on one printed circuit board.
- This allows to interconnect suitability for high current and high functional density.
- The inner layer thus contains both thick copper zones for the performance areas and a standard copper layer thickness in which the logic areas are placed.

Advantages of the Combi Board:

- Cost reductions through fewer expenses in logic and production
- No connectors or cables are needed
- Combination of different layer structures is possible
- High reliability
- Reduction in weight compared with previous solutions is possible
- In combination with FR4-Flex technology, required space is very small in comparison with standard version
- Temperature of use – 40 °C to +140 °C.
IMS stands for »Insulated Metal Substrate«. Special materials are used, providing high thermal conductivity in combination with good electrical insulation. Thus, the printed circuit technology is particularly characterised by a very good heat management. A full-surface massive metal back ensures a quick and efficient temperature spread and thus prevents hot spots. IMS boards generally have aluminium backs, however, this does not apply to SCHWEIZER. The company uses copper carrier board, among other aspects, because copper is known as a circuit board material and is compatible with all circuit board processes. Hence, many empirical values known from other printed circuit technologies can be also applied to the IMS board.

**IMS Board**

IMS @ a glance:

- **Surfaces:** OSP/ chem. Sn/ chem. Ni-Au
- **Possible build ups:** single layer/ 3 layers/ 5 layers

**Insulation properties:**
- Breakdown strength: > 4 KV
- Thermal conductivity: >= 2 W/mK
Inlay Board

The printed circuit board needs copper wires with large cross-section to conduct high currents. Since device dimensions restrict the circuit areas, the only available option is to enlarge the conductor thickness. By using copper inlays up to 2 mm in thickness, it is possible to produce areas on the printed circuit board that allow current peaks significantly higher than 1,000 A. Inlays are also used only for the heat dissipation from the components.

Advantages of the Inlay Board

- Improved heat and current conductivity:
  By means of an optimised heat and current path in comparison with conventional copper pressing inlay technology

- Despite integrated heatsink, a multi-layer structure is possible.

- Improved mechanical strength:
  The copper inlay is embedded in the resin matrix by means of the laying and the pressing process
- This technology prevents cracks that can occur if the conventional technology is used (pressing of inlays)

- The technology can be implemented by means of the standard production processes of the printed circuit board

- The larger cooling surface facilitates heat dissipation and increases the life span of the unit. Life cycle costs can be lowered

- Suitable for many high-current applications
  Short-term current peaks of > 1,000 A are possible

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**Summary: Qualitative overview of solutions for power electronics**

<table>
<thead>
<tr>
<th>Thumb values</th>
<th>„Thick Copper“</th>
<th>Wirelad ™</th>
<th>Combi Board</th>
<th>IMS Board</th>
<th>Inlay Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logic and power (on one level)</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Current-carrying capacity</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Costs</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Heat dissipation properties</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Miniaturising</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>3D capability</td>
<td>+</td>
<td>+++</td>
<td>++</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

+++ best solution – not possible
Thermal Vias

Thermal vias are applied as additives for heat dissipation and are often used in practice.

Special calculation tools can be used to determine the exact number of the required vias. Thermal vias can be also sealed with dielectric fluid and coated.

Advantages of thermal vias:
- Standard circuit board process
- High adaptability via the number of bores

Water Board

If all the presented solutions for high current and passive cooling are not sufficient, you can use Water Board for active cooling.

We have experience with different flow channels and Water Board can, of course, be combined with other suggested solutions for power electronics and embedding.
Technology outlook

Power embedding with the p² Pack

Conclusion:

The overall economic analysis of a device focuses on efficiency, manufacturing costs and long warranty.

Intelligent printed circuit board concepts can actively contribute to quality and performance improvement not only of PV inverters. It is important to know already in the product development phase the possibilities of the printed circuit board designs and to choose the best solution, considering the overall economic aspects.
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