

The Design Concepts of Power Modules

These power modules feature a variety of topologies

This article describes the underlying design concepts for Vincotech's flow 0, flow 1 and flow 2 families, as well as flowSCREW 2s and the new flowSCREW w housings. It also discusses the pros and cons of Press-fit pins, DBC substrates, and stress-relief zones.

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The offering extends beyond standard motor drive topologies such as CIB / PIM, PACK, and half-bridge modules to encompass products designed specifically for PFC, welding, solar, and UPS applications. Motor drives run at moderate switching frequencies, typically 4 kHz to 16 kHz. Other applications, however, need higher frequencies to improve the given system's overall efficiency. Consequently, the company has qualified a wide range of switches and diodes to satisfy customers' varying needs. Vincotech's modules feature NPT and PT IGBTs as well as MOSFETs, SiC diodes, and SiC switches. Beyond merely offering standard product, Vincotech routinely tailors modules to the customer's specifications.

Topologies and technologies

This article explains the different types of assemblies and topologies using a module with a 3-level topology as an example. The figure below shows a flow 0 module with this NPC topology.



Figure 1: flow0 module with three MOSFET and IGBT in parallel

Freely variable pin positions

The modules technology allows pins to be positioned freely. Designers can place pins precisely where they need to go, near switches or diodes. This reduces the length of bond wires and, by extension, inductivity. Applications requiring low inductive paths - for example, for the circuit between DC+ to neutral and neutral to DC- in an NPC topology - benefit tremendously. Overvoltage

spikes can be a problem in modules with fixed pin positions and longer bond wires. Not so with variable pin allocations: Designers can tailor layouts to reduce overshoot when powering up. This concept also makes the most of DBC space and enables faster switching speed. In the final reckoning, one of the secrets of high-performance modules is a low inductive design, which goes a long way towards explaining Vincotech's success in this area.

Solder pins and Press-fit pins

Vincotech offers modules with standard solder pins and optionally with Press-fit pins.

The figure below shows two DBC substrates, one with a set of solder pins, the other with Press-fit pins.

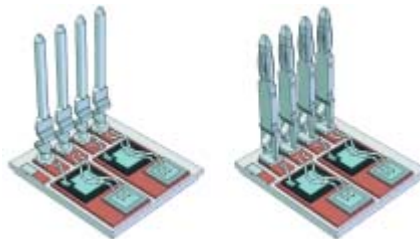


Figure 2: DBC substrates with cone-shaped solder pins and Press-fit pins

The pin positions for both variants, solder-pins or press-fit pins, are identical for any module. The solder pin's diameter is 1 mm and the Press-fit pin requires a 1.45 mm hole, so the same PCB type may be used for either technology. For more details, please consult the appropriate application note.

DBC materials

AlN (aluminum nitrate) DBC substrates extend the power handling capacity of flow 0 and flow 1 modules. AlN DBC substrates' thermal conductivity is about six times

greater than Al₂O₃ (aluminum oxide) DBC substrates'. This reduces R_{th} values to a level comparable to that of modules with a base plate, for instance, the flow 2.

DBC sizes:

Different sizes of DBC substrates are used in flow 2 modules to achieve maximum flexibility and performance. These modules consist of a copper base plate that holds the DBC substrates in place and improves thermal spreading. Such a construct achieves lower thermal resistance than modules with Al₂O₃ DBC substrates. Another advantage of a base plate is its thermal capacity, which can be beneficial in the event of brief power surges. Figure 3 shows an NPC configuration with three DBC substrates and a CIB/PIM layout requiring just two DBC substrates.



Figure 3: An NPC module and a CIB / PIM module

Every millimeter of bond wire matters, so DBC substrates come in different sizes to improve the utilization factor and efficiency.

Thermal interface

Although electrical parameters are very important, they are not the only key performance benchmarks. Thermal resistance to the heat sink is another vital factor. The dies, DBC substrates, and base plates' thermal conductivity is much higher than legacy thermal compounds'.

This is why the developed stencils and silk screens to apply thermal components to its modules. Customers may use these stencils to apply their own thermal interface material or order modules with pre-applied phase change material.



Figure 4: A module with Press-fit pins and phase change material

Vincotech uses a phase change material that may be applied via the standard stencil printing process. Both options, solder pins and Press-fit pins, are available with pre-applied phase change material.

To learn more about this special technology and the associated processes, please consult the application note for Press-Fit pins and the handbooks for the given product. Tips and design rules for press-in tools are also available and will be provided on request.

Defined step height and pre-bent DBC substrates

After mounting, pressure is applied to the power module and heat sink to spread the thermal compound well and squeeze out excess grease. Usually the interface material's thermal conductivity is much lower than that of the module's inner layers and heat sink. This is why every effort should be made to ensure metal-to-metal contact at every possible point. The DBC modules have a pre-bent convex DBC as shown in the figure 5.



Figure 5: Module with pre-bent DBC

The die in the center of the DBC often runs at the highest temperature, creating a hot spot in the middle of the module. This is why pre-bent DBC substrates are used to provide a good thermal contact to heat - sinks. After mounting, the straps apply considerable pressure through the DBC to the heat - sink, so a step height of a few micrometers also helps ensure a good thermal contact.

Stress-relief zone

A special patented S-bend provides a stress-relief zone that enables the pin to work in the z-direction. It is located at the bottom of each pin near the DBC, which is illustrated in Figure 2. The pre-bent DBC substrates necessitate this stress-relief zone. It serves to compensate for housing and application tolerances during the assembly process. Vincotech's pins also help control for heat sinks or PCBs' thermal expansion.

Passive components assembly

Vincotech also assembles passive components such as shunts, resistors, and capacitors to improve efficiency and flexibility. A small capacitor placed between DC+ and DC- can be very beneficial in some applications with high switching frequencies because it helps minimize the current loop. This is why modules such as the H-Bridge are available with and without a built-in ceramic capacitor as a standard feature. The *flowIPM 1B* attests to Vincotech's manifold abilities in assembling passive components.



Figure 6: The *flowIPM 1B* module

This module consists of rectifier diodes, inverters IGBTs, and freewheeling diodes; a PFC switch and diode are optional. Additional components include the driver IC, bootstrap diodes and capacitors, shunts, and various gate resistors for powering up and down. In contrast to other modules, the *flowIPM 1B* is built on a standard ceramic substrate rather than the usual DBC substrates. All high-tech tasks such as structuring tracks and assembling semiconductors are performed in-house.

High-power modules

Vincotech responded to growing demand for low-inductivity solutions by developing the *flowSCREW 2s* modules. They are the product of experience and insight gained with the current standard modules and their underly-

ing technologies. The *flowSCREW 2s* is the first module on the market suitable for IGBTs with high switching speeds. Designed to reduce switching losses and make paralleling much easier, these modules afford designers unprecedented opportunities to minimize applications.



Figure 7: Three *flowSCREW 2s* modules connected via a common PCB

A small added multilayer PCB is sandwiched between the two DBC substrates to reduce stray inductance to 7 nH.

The latest package is the *flowSCREW 4w* module. Engineered to achieve the greatest flexibility and efficiency, it cuts stray inductance to less than 5 nH, regardless of the integrated topology. Pins may be positioned flexibly along the main path of a large multilayer PCB leading to the screw terminals. Two base plates split one large system with a given coefficient of thermal expansion into two independent systems. This serves to make solder layers far more reliable. The module can accommodate many topologies including rectifiers, half-bridges, six-packs, and NPCs, to name just a few of the most important. It is the module of choice for solar, UPS, and other applications demanding highest efficiency. With 600 A chip current implemented in a mixed-voltage NPC topology, it supports applications up to 250 kW.

Conclusion:

Designers in search of utmost efficiency and reliability for their applications will find the features and benefits they seek in Vincotech modules. Designed for a power range from 500 to 1700 V and from 4 to 600 A, these power modules feature a variety of topologies and technologies to satisfy the needs of the most diverse applications.

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