Combining the Features of Modules and Discretes in a New Power Semiconductor Package

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Abstract

A new package for power semiconductors has been developed: Power semiconductor chips are soldered onto a DCB ceramic substrate together with a lead frame with up to five pins. Subsequently chips and DCB are covered by molding compound. This packaging method combines the technologies of module and discrete assembly. Thus the resulting component provides a combination of the characteristics of both families of devices:

The new components are internally isolated from the heatsink they will be clamped onto. The pins are soldered into a printed circuit board; any circuit with an adequate number of pins can be incorporated in the package, using any kind of chip — such as MOSFETs, IGBTs, thyristors, diodes — and any topology. The pinouts are defined according to the requirements of electrical circuit design — for example avoiding current loops —, which — together with the very compact volume of the package — faciliates a low inductive design of power section. Designing scalable power sections for a broad range of nominal power is easy due to the possibility of connecting devices in parallel. Reliability is expected to be comparable to modules' because of the matched thermal expansion coefficients of silicon chips and DCB ceramic substrate they are soldered onto.

These features described in this paper make the new family of components advantageously applicable in a variety of converters, such as for industrial and automotive drives or for power supplies.

1 Packaging Technology

The new package will be named Isoplus I4-Pac™ in the following. Its top and bottom view are shown in figure 1. Basically, it looks similar to conventional discrete components such as TO247; however significant differences become obvious regarding the cross section in figure 2: The chips are not mounted on a solid metal leadframe, but on a DCB substrate [1]. It consists of a ceramic substrate with copper layers bonded onto its top and bottom side. The bottom copper, used to transfer the operational power dissipation to the heatsink, is visible in the package's bottom view figure 1. The ceramic isolates it from the top copper layer, which may be structured corresponding to a printed circuit board as visible in figure 2. The top copper carries the chips, whose upper side is wire bonded towards the DCB pattern and the pins. To provide electrical and mechanical protection, this subassembly is transfer molded, thus creating the typical black plastic package.

Two versions of the package with different pin distances have been successfully introduced. Their outlines are shown in figure 3. Height and length correspond to TO247, width to TO264 industry standard packages. The experiences gained by IXYS' proprietary DCB production and discrete assembly, together with manufacturing the already introduced TO247 like Isoplus247 package [2], have helped to install the assembly process.

The construction as described offers several benefits to the user of the components:

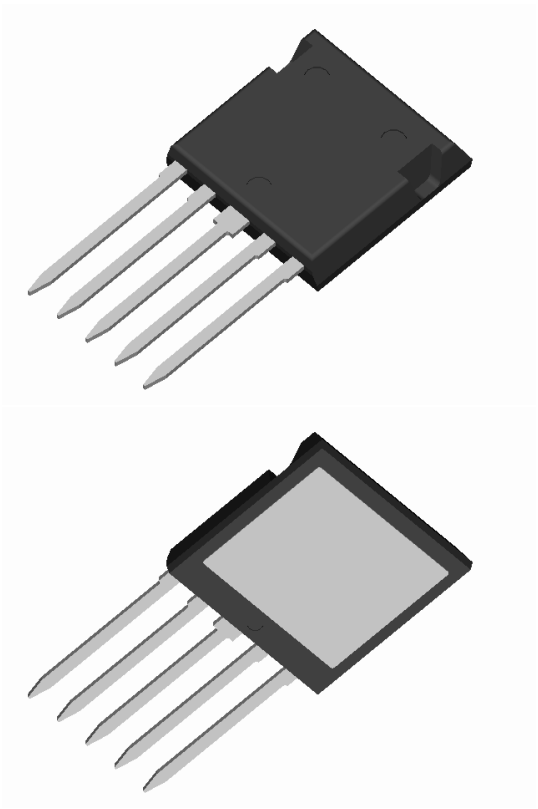

Figure 1: top and bottom view of five pin version

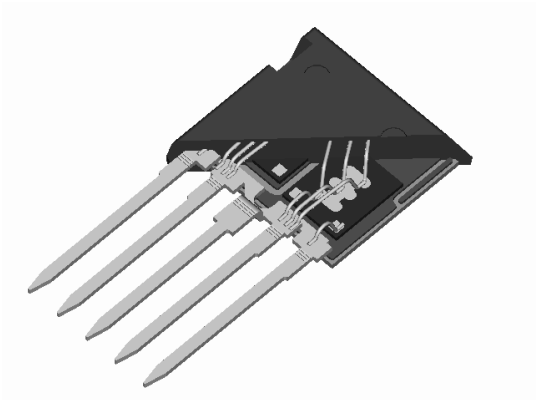

Figure 2: cross section of five pin version

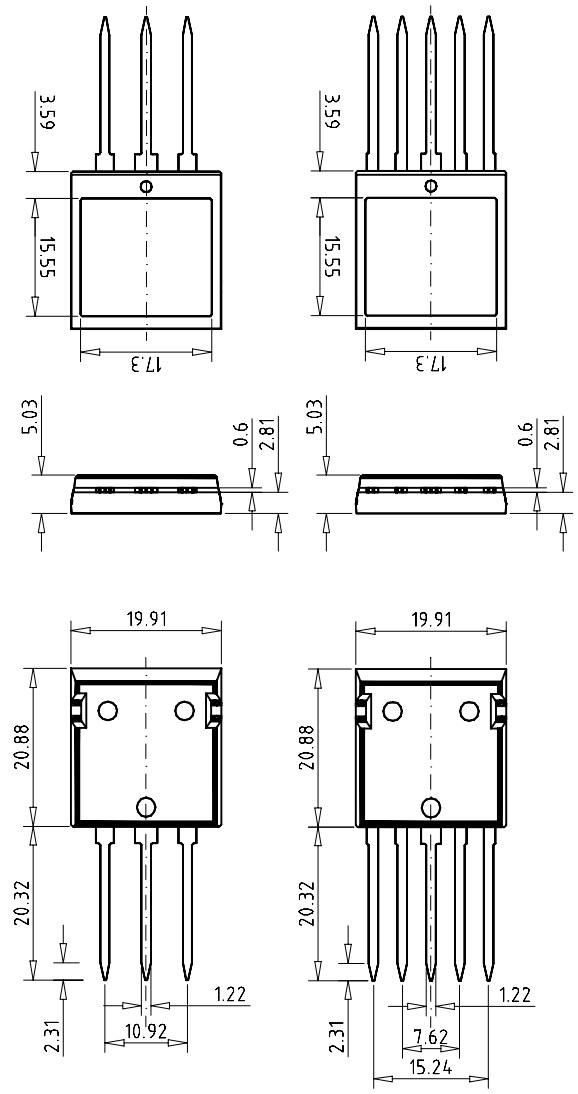

Figure 3: dimensional drawing of three pin (left) and five pin (right) version

- A large variety of topologies with a all kinds of power semiconductor switches can be incorporated.
- The pinout can be defined in an electrically favourable way.
- The power circuit is internally isolated from the heatsink.
- A heatsink with an appropriate geometry permits to obtain a creepage distance between pins and ground of more than 6mm without additional measures.

- Standard mounting processes can be used: The pins are soldered into a printed circuit board. The package is simply directly clamped onto the heatsink with an industry standard spring [3], generally using some thermal compound to achieve a good heat transfer between the package and the sink. This mounting procedure allows considerable savings, because no external isolator is required.
- High reliability is achieved due to the corresponding thermal expansion coefficients of silicon chips and DCB substrate.

The following section 2 gives more details on several products with reference to the general features previously outlined. Section 3 shows their significance in exemplary applications.

2 Topologies, Components

This section presents some components in Isoplus I4-Pac™ package recently developed or currently under development. Of course there is a variety of further possibilities. Numbering of the pins as used in the following is shown in figure 4.

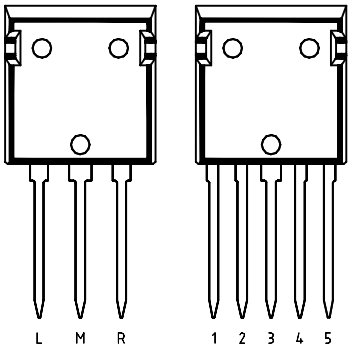

Figure 4: pinout of three pin (left) and five pin (right) version

2.1 Single Switches

Single switches can be manufactured using all types of power semiconductors and with three different kinds of pinouts:

- The three pin package — see figure 4 (left) — will be used with the same pinout as TO247 or TO264 components, as a drop in replacement for the latters by isolated components with larger chips or smaller footprint respectively.
- A high voltage version will be realized based on the five pin package, omitting pins and thus enlarging the strike and creepage distances to the required length — see figures 4 (right) and 5. Please also note the position of the gate besides the source or emitter terminal, which is layout friendly and will increase noise immunity.
- A high current version will be realized with the five pin package, paralleling two pins each in the main current path — see figures 4 (right) and 6.

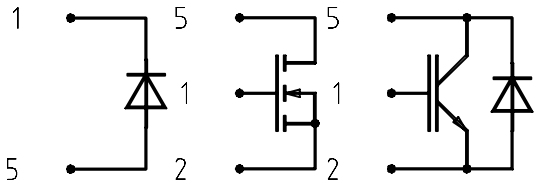

Figure 5: high voltage single switches with diode (left), MOSFET (center) or IGBT with diode (right)

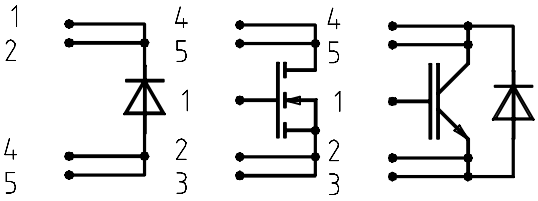

Figure 6: high current single switches with diode (left), MOSFET (center) or IGBT with diode (right)

Table 1 gives basic ratings of exemplary single switch components in Isoplus I4-Pac™ package.

Table 1: single switches in Isoplus I4-Pac™

name	type	voltage rating	current rating	pinout, see fig. 4
IXFF24N100	MOSFET	$U_{DSS} = 1000V$	$I_{D90} = 17A$	G→L, D→M, S→R
IXBF9N160	BIMOSFET	$U_{CES} = 1600V$	$I_{C90} = 5A$	see fig. 5 (right)
IXBF40N160	BIMOSFET	$U_{CES} = 1600V$	$I_{C90} = 18A$	see fig. 5 (right)
IXDF30N120D1	IGBT + diode	$U_{CES} = 1200V$	$I_{C90} = 32A$	G→L, C→M, E→R

2.2 Phaselegs and Choppers

The five pin package can incorporate a complete phaseleg using MOSFETs, IGBTs with free wheeling diodes or thyristors respectively as shown in figure 7.

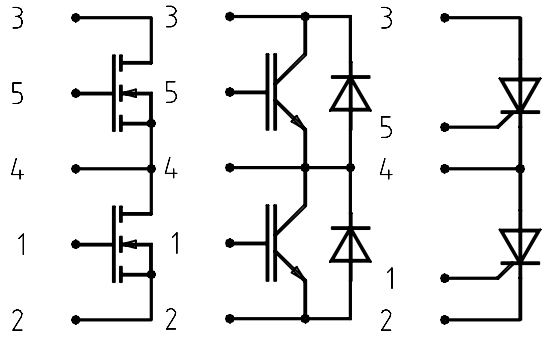

Figure 7: phaselegs with MOSFETs (left), IGBTs with diodes (center) or thyristors (right)

Please note the features

- small current loop between plus (3) and minus pin (2), thus low inductance
- neighbouring gate and source, emitter or cathode pins respectively (5 and 4, 1 and 2) for easy and noise immune drive

which enhance user friendlyness of these components above the market standards known from discrete components.

Of course, boost- and buck choppers can be generated based on the phaselegs, replacing one transistor by a diode. However, the possibilities even go further, because the structurability of the DCB as explained in section 1 permits to introduce a series connected and thus exceptionally fast free wheeling diode. As examples, this kind of boost and buck choppers with MOSFETs and IGBT are shown in figure 8.

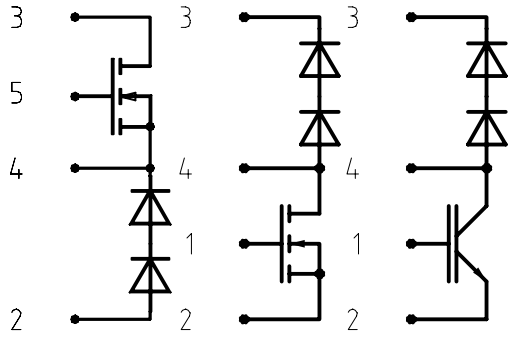

Figure 8: buck chopper with MOSFET (left), boost chopper with MOSFET (center) and IGBT (right), all with series connected free wheeling diodes

Please additionally note, that all bridge configurations — phaseleg, boost and buck choppers with the different types of chips — have the same pinout. This faciliates the designers' layout work and enhances the flexibility to use printed circuit board layouts several times for different purposes.

In table 2, again basic ratings of exemplary phaseleg and chopper components in Isoplus I4-Pac™ package are given.

2.3 Rectifiers

Another obviously advantageous topology in the new Isoplus I4-Pac™ package is a single or three phase rectifier as shown in figure 9 and rated in table 3. Again an application friendly pinout has been achieved with the AC pins being separated from the DC pins.

Table 2: phaselegs and choppers in Isoplus I4-Pac™

name	type	voltage rating	current rating	pinout, see fig. 4
FMM75-01F	MOSFET phaseleg	$U_{DSS} = 100V$	$I_{D90} = 50A$	see fig. 7 (left)
FDM21-05QC	MOSFET buck	$U_{DSS} = 500V$	$I_{D90} = 15A$	see fig. 8 (left)
FMD21-05QC	MOSFET boost	$U_{DSS} = 500V$	$I_{D90} = 15A$	see fig. 8 (center)
FID35-06C	IGBT boost	$U_{CES} = 600V$	$I_{C90} = 25A$	see fig. 8 (right)
FCC21-08io	thyristor phaseleg	$U_{RRM} = 800V$	$I_{TAVM90} = 21A$	see fig. 7 (right)

Table 3: rectifiers in Isoplus I4-Pac™

name	type	voltage rating	current rating	pinout, see fig. 4
FBO16-08N	single phase	$U_{RRM} = 800V$	$I_{FAVM90} = 16A$	see fig. 9 (left)
FUO22-08N	three phase	$U_{RRM} = 800V$	$I_{FAVM90} = 22A$	see fig. 9 (right)

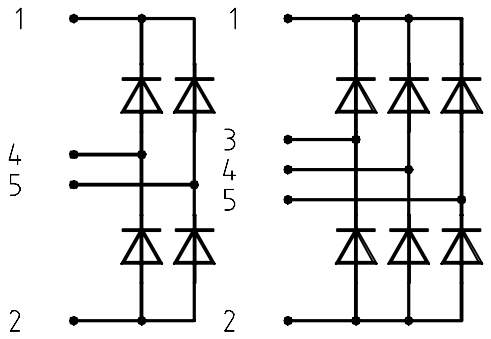

Figure 9: single (left) and three phase rectifier (right)

3 Applications

Some typical applications of Isoplus I4-Pac™ components with topologies and using components as desribed in section 2 are discussed in the following:

3.1 Industrial and Automotive Electrical Drives

Self commutated converters for AC drives use phaseleg configurations as shown in figure 7 (left and center). This means, that a very compact power section for an AC drive can be built, using three phaseleg Isoplus I4-Pac™ components as listed in table 2. The power range can easily be enlarged by parallelling several components without the penalty to thus increase the low stray inductances between printed circuit board and chips, which is avoided by the phaseleg topology.

Switched reluctance drives require several boost and buck components according to figure 8 and table 2, DC drives one boost or buck chopper or a thyristor bridge according to figure 7 (right) and table 2. Proceeding and features using Isoplus I4-Pac™ components will be the same as described for AC drives.

In industrial drives, the inverter bridge may be complemented by a brake chopper — again see figure 8 and table 2 — and a single or three phase rectifier — see figure 9 and table 3. The advantages of this kind of converter – brake – inverter power stage using Isoplus I4-Pac™ components compared to standard discrete solutions are obvious — such as lower design and mounting expense, better operational behaviour and increased reliability.

Components like FMM75-01F are aiming at a different kind of electrical drives, mainly in vehicle applications: The Isoplus I4-Pac™ components may contribute to optimize automotive auxiliary drives with adaptable nominal power particularly for the new 42V supply and drives in battery supplied vehicles.

3.2 Power Supplies and Power Factor Correction

Figure 9 and table 3 deal with single and three phase rectifier components in Isoplus I4-Pac™ package; they can be used in a variety of power supplies.

A recent trend in power supply technology leads to power factor corrected rectification. This is partially due to the standards [4][5], limiting the harmonic distortion of mains input currents, but additionally this topology offers the benefits to provide a wide input voltage range and to gain the highest amount of active power out of a plug with a given fuse. Due to the availability of ICs incorporating the control functions — such as [6] —, single phase PFC rectifiers can be built up in a simple and cost effective way. Their power section consists of a single phase rectifier in series with a boost converter [7].

While this topology can advantageously be integrated into a power semiconductor module for nominal powers above some 1kW, mainly discretes have been used for lower power levels. However part count and again mounting effort is high for conventional discrete solutions. This can be avoided using two Isoplus I4-Pac™ components — a single phase rectifier such as FBO16-08N according to figure 9 (left), table 3, and a boost chopper such as FMD21-05QC or FID35-06C according to figure 8 (center or right), table 2. The chopper consists of a MOSFET with low gate charge or a fast IGBT and two series connected fast diodes representing the free wheeling diode with a reverse recovery behaviour outperforming single chip solutions [8][9], which is particularly important for the switching frequencies of 50kHz to 100kHz typically used. The user friendly pinout of both components leads to a current flow avoiding wire crossings on the printed circuit board.

4 Conclusion

A new family of power semiconductor components in a recently developed package has been presented. The package combines an outline comparable to discrete components with features of multi chip modules, such as isolation from the heatsink and the capability to integrate a variety of circuits. Topologies have been suggested and power semiconductor components have been rated; typical applications have been discussed. The features of the new packaging concept make expect a broad use of the components belonging to the new Isoplus I4-Pac™ product family in existing and emerging applications.

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