Innovations in Technology Brings the Thyristor into the 21st Century

The latest market research reports show an expected annual growth rate of 10 to 12 % for power modules in general. For today's more recent fashion - the IGBT module, growth is well understood but a more unlikely candidate for a major factor of this growth will be from the often overlooked Bi-Polar module. Indeed research indicates that the Thyristor and Diode module market is growing in line with the IGBT power module markets. IXYS continues to challenge the historic design limits attributed to thyristor and diode technology with its "MORE POWER LESS PACKAGE" strategy. IXYS directs its designers to make use of improved structures, production processes and materials to maximize the power to weight ratio and providing attractive solutions to today's more complicated problems. The target is to improve current density, reducing module size and raising efficiency expectations in a space which has seen little evolvement from a level developed decades ago. IXYS illustrates its commitment for continuous innovation by highlighting several new developments in die design, packaging technology.

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Thyristor technology is known already for many of years and is often the first power product to be taught in power electronic laboratories. IXYS' Lampertheim facility in Germany introduced commercially available thyristor technology in 1961. The thyristor module got a real boost in reliability when IXYS introduced its Direct Copper Bonded (DCB) based modules in 1981 which formed a new standard in modules that competition continue to try and emulate. The DCB substrates, which provide a rugged isolation layer for today's modules, are produced in-house at IXYS retaining focus on the development of this technology as well as operational benefits. All these years of experience resulted in not one but several available thyristor technologies. Figure 1 shows a simplified overview of all available thyristor technologies within IXYS. CWP is the standard thyristor die format with the anode on the back (soldered) side and the cathode on top of the die. The gate current as related to the cathode is positive. The next design step was to create a new anode-gated thyristor with the cathode on the backside driven by the need to create a phase-leg on a common base for the AC terminal. Here the gate current has a negative convention. Further developments indicated that in some mechanical constructions a thyristor with the contacts reversed were of interest. So the cathode-gated CWRP was developed featuring the cathode at the back (soldered) side and anode on the top. Furthermore IXYS developed a standard CWP that could turn on not only with positive but also with a negative gate current. This allowed in combination with a CWN die to build up a TRIAC with a simple yet effective two-die-design.

	CWP	CWRP	CWN	CWRN	CWP-N
Anode	Backside	Topside	Topside	Backside	Backside
Cathode	Topside	Backside	Backside	Topside	Topside
Gate side	Cathode	Cathode	Anode	Anode	Cathode
Gate current	positive	positive	negative	negative	positive negative

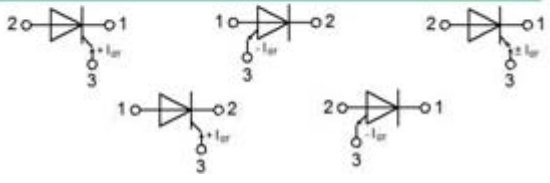

Figure 1: Thyristor technology overview

The different die technologies available in IXYS give flexibility in the design of bipolar solutions in many different soft starter, general inverter, UPS, current control and pulse circuit applications. Just as an example, the combination of the anode and the cathode soldered thyristor in a discrete package can be mounted to a non-isolated backplane or heat sink, creating a half bridge configuration with less materials, weight and size.

The ComPack Module

There are also other benefits by combining the cathode- and anode-soldered thyristor dies. One example is the ComPack Thyristor module. The ComPack is a soldered module with current ratings up to 800A using a combination of the anode- and cathode-soldered technology for thyristor phase-leg configurations. The maximum junction temperature of the thyristor dies is 140°C. The bus-bar connections are directly contacted with the top side of the dies.

The inverse thyristor technology together with a solderable top side metallization makes this possible. So as shown in Figure 3 the line connection is directly connected to the top side cathode and the Neutral is connected to a top side anode. This shows optimal usage of the different technologies to get the highest current density possible. The result is a small and light module with only a weight of 500 grams. It is about 1 kg lighter than its direct replacement which is using pressure contact technology. Additional to this the footprint of the ComPack is about 30% smaller than the competitor illustrating how IXYS' MORE POWER, LESS PACKAGE design philosophy can reduce transportation costs across the whole of the value chain from

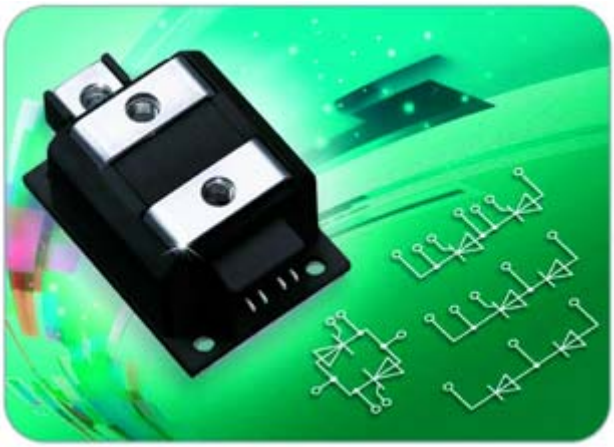

Figure 2: ComPack module

supplier to the very end customer . This all is enabled by using the latest IXYS innovative thyristor technologies and combining it with new module designs.

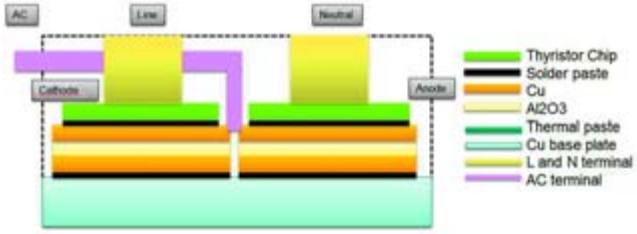

Figure 3: improved module current density (ComPack)

IXYS' Direct Copper Bonded (DCB) ceramic technology provides a high isolation voltage of up to 4800 V which is in accordance with Underwriters Laboratory (UL) requirements. With the adapted copper base plate the ComPack concept achieves very low thermal impedance whilst improved use of materials helps to reduce the module weight. The improved design goes further to support longer term reliability under the highest power output operation by optimizing the thermal interfaces from its heat flow to the heat sink. The main difference compared with existing competitive module offerings is shown below in Figure 4. The thermal resistance has been improved by reducing the DCB thickness from 0.63 mm to 0.38 mm where the copper thickness on both sides of the DCB stayed constant. Additionally in the ComPack module the thinner DCB is soldered to the copper base plate where in the Y1-Pack this connection is established with thermal paste. This significantly improves the thermal impedance (Rth) by a minimum of 30%.

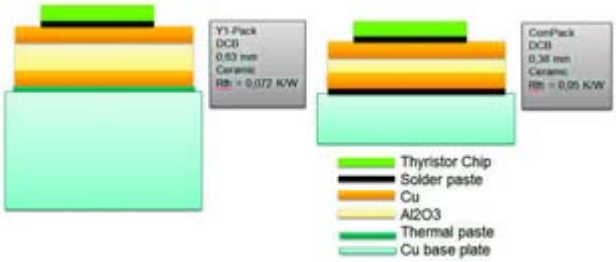

Figure 4: improved thermal construction (ComPack)

Configurations are traditionally phase-legs featuring two thyristors or diodes in one module. Also single die parts and thyristor/diode combinations are available. Further development is planned to widen the silicon options to take benefits of the mechanical module advantages that the ComPack provides including an un-isolated TRIAC version for higher current ranges than are typically available today. With this development, IXYS is allowing the designer to switch more power than historically existing at a lower weight than before thereby facilitating higher power densities, greater material efficiency and lower

system cost. It is often a priority of customers to get access to new productivity in the traditional outlines and bi-polar technologies that are ubiquitously implemented in today's UPS, Motor drive and power converter topologies. IXYS are confident that by the adoption of new outlines illustrated by the ComPack, customers will enjoy the benefits of the bi-polar power product solutions.

The IXYS TRIAC

There are currently available many thyristor and TRIAC products which provide solutions for an extremely wide set of applications. One of the main topologies is that of an AC-Controller that traditionally is made up from two back to back thyristors. However, this topology is implementing standard anode back (solder) side and cathode top side create challenges for low cost reliable modules. By using IXYS reverse contact die technology building up AC-Controllers with two complementing thyristors offer several advantages and opportunities. Using a standard anode back and cathode back die technologies allows IXYS to build the AC-Controller in un-isolated packages, and with adapted gates of anode- and cathode-gated thyristors that allow positive and negative gate currents to extend control to the different quadrants (Figure 5). Most obvious advantage is of course the use of just one gate unit. With it the possibility of using packages with just three terminals becomes achievable. Less obvious is the benefit that the specially designed thyristors keep their general advantages compared to a standard TRIAC. Especially useful to the product designer are the higher dv/dt and di/dt stability inherent in this technology which can reduce the need for external components. This double die solution removes the weak links in standard TRIAC design in terms of limitations in current size and limitations in the forward and reverse blocking voltages. Using this technology power TRIACs for forward currents in excess of 25A and blocking voltages in excess of 1000V are finally commercially viable. This greatly improves the TRIAC portfolio in discrete packages such as standard TO-220 , TO-247 or similar packages that currently have these limits. Engineers designing products for world-wide application often have to produce two designs to take into account varying supply voltages. The new IXYS TRIAC allows them to select just one design for all their global customers. First released product is a 60A TRIAC with 1200V available in TO-247, ISO247 and TO-268 (D3-Pak): CLA60MT1200HB. IXYS have a full portfolio planned in order to increase the voltage and current ranges for this technology for such applications as motor control, soft start, power control heaters and lighting.

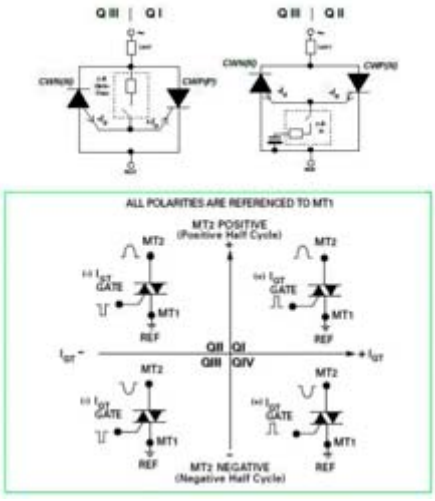

Figure 5: Thyristor configurations and Quadrant operations

The Reverse Conducting Thyristor (Triode)

One of the latest innovations from IXYS is the development of a fast switching thyristor that includes a monolithic body diode. This development results in a single die solution to fit into various power topologies. The resultant reverse conducting thyristor (Triode) provides an extremely fast turn on with high efficiency. In previous silicon solutions the designer would be limited to multiple die solutions which not only increase the complexity, space and cost of the solution but allow for unwanted parasitic inductances that can have the effect of reducing efficiency or reliability. The integrated diode in reverse polarity (anti-parallel) allows the usage of this thyristor in resonant discharge applications. The Triode is a direct replacement for spark gaps in ignition circuits for High Intensity Discharge (HID) lamps for automotive, street or commercial lighting applications. Solid state solutions have many benefits over spark gaps including an improved repeatability of the switching characteristics over the lifetime of the component. Also other electrical discharge applications such as electrical fences or simple resonant circuits are predestinated for a Triode having many operational benefits. First product of this new design is packaged in a TO-220 outline: CLA30EF1200PB being a 30A 1200V reverse conducting thyristor (Triode).

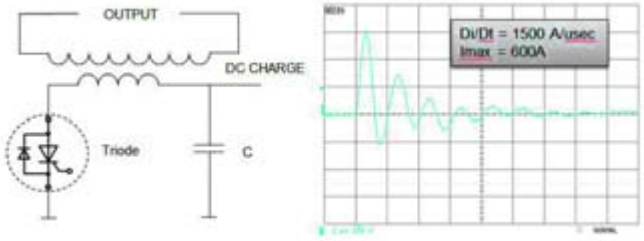

Figure 6: Typical Triode application circuit

Conclusion

IXYS has shown innovations in bi-polar die technologies and in packaging design. IXYS has illustrated this to describe various new thyristor technologies and improved thermal constructions which combined can be utilized to provide soldered thyristor modules up to 800A to the market. Additionally creative implementation of this newly developed technology can realize a wide product range of single-gated AC-controllers. The new technology allows access to higher current higher voltage TRIACs. Mechanical spark gaps can be replaced by the monolithic reverse conduction thyristor (Triode) which is another step in the improvement in efficiency and reliability of several applications. The products described in the article are summarized in Figure 7, but represent only a small percentage of the new product development activities and available new product portfolios in IXYS. Therefore bi-polar technology which may have been eclipsed by more fashionable products such as the IGBT in recent times, is in fact benefiting from the attention it deserves at IXYS to drive innovation well into the 21st century.

Part number	Vrrm / V	ITav / A	Configuration	Package
MDMA600P1600CA	up to 2200	600	Diode Phase-leg	ComPack
MCMA700PD1600CA	up to 2200	700	SCR/Diode Phase-leg	ComPack
MCMA800P1600CA	up to 2200	800	SCR Phase-leg	ComPack
CLA30E1200HB	1200	30	SCR	TO-247
CLB30I1200HB	1200	30	SCR - Anode Gated	TO-247
CLA60MT1200NTZ	1200	60	TRIAC	TO-268 (D3-Pak)
CLA60MT1200NHB	1200	60	TRIAC	TO-247
CLA30EF1200PB	1200	30	Triode	TO-220

Figure 7: Product table

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