miniBLOC™
the polyvalent power package

The miniBLOC is an isolated power semiconductor package particularly suited for use in power conversion equipment spanning the range of 1 kVA - 50 kVA, where an optimum mix of good power density, high speed switching, versatility, wide device choice, ease of application and long term reliability is a must.
IXYS' miniBLOC product range of Power MOSFETs, IGBT/FREDs and dual FREDs is eminently adaptable to nearly all popular power conversion architectures, like single-ended, asymmetric or full bridge converters, phase legs for AC motor drives, AC switches, high frequency centre-tap or bridge rectification, and many others. As such, these products may be advantageously specified for use in high frequency AC or DC motor drives, high power SMPS, welders, DC choppers, UPS systems and similar power switching circuits.

What is a miniBLOC?

As its name suggests, the SOT-227B outline miniBLOC is a **mini**ature power **BLOC**K, conveniently bridging the power gap between inexpensive discretes in TO-247 or TO-218 packages and costlier, full-sized modules in TO-240, 34 mm-wide and larger housings. Being a mass-produced, injection-moulded design, the miniBLOC shares with its discrete siblings the virtues of small size, excellent reproducibility and low intrinsic package cost, while retaining the user-friendliness of big modules through provision of a fully-isolated base plate, four rugged high-current screw terminal connections, and a wide choice of circuit topologies in the same housing. The SOT-227B is suitable for the packaging of a wide variety of device technologies - Power MOSFETs, IGBTs, **F**ast **R**ecovery **E**pitaxial **D**iodes (FRED), Schottky diodes, thyristors, and conventional rectifiers among others.

At this writing, IXYS offers the miniBLOC with Power MOSFET, Thyristors, IGBT/FRED, and dual-FRED chip combinations (Table 1). MOSFETs are rated from 70 V up to 1000 V each containing two industry-standard size 7 dice (8.8 mm x 7.3 mm) in parallel, with appropriate load-sharing arrangements; 25°C current ratings are from 15 to 200 A respectively. In common with all Power MOSFETs, these products incorporate an intrinsic bypass diode. In the HiPerFETs this diode is improved by an IXYS specific process to reach recovery behaviour similar to a FRED diode. Therefore the diode is fully usable in phaseleg applications.
IGBT miniBLOCs are 600 V, 1000 V and 1200 V rated. For each voltage class exist models optimized either for low $V_{CE(sat)}$ or fast collector-current fall time. Because IGBTs are bipolar structures with a PNP output stage, collector current fall time is related to stored charge in the transistor base region. To accelerate charge removal and speed up switching, the structure may be irradiated to decrease minority-carrier lifetime. Unfortunately, semiconductor physics dictate that low lifetime equates to high on-state losses, hence the desirability of two variants. Choice between the two is governed primarily by operating frequency and duty cycle. In inductive-switching applications, each time the IGBT is gated-off its collector voltage rises just as soon as collector current starts to fall; turn-off energy is therefore proportional to current fall time and switching losses to frequency.
An exaggerated current-"tail" time causes high power losses. Conduction losses, conversely, are related to $V_{CE\ (sat)}$ and duty cycle; in low frequency high duty-cycle applications, conduction losses swamp out switching losses. As a general rule, then, fast IGBTs are preferred for high frequency applications, low $V_{CE\ (sat)}$ types for the rest. Cross over frequency for IXYS IGBTs is 5 - 8 kHz. Models destined for high frequency use are identified by an "A" suffix in the part number-IXSN 52N60 **A**U1, IXSN 35N120 **A**U1whereas low conduction loss types bear **no A-** suffix IXSN 62N60U1, IXSN 35N100U1

All IGBT miniBLOCs, "A" and non-"A", contain one size 7 IGBT chip connected in antiparallel with a FRED. This topology is standard for inductive-load switching circuits like AC motor-drive inverters, providing a return path for reactive current.

Another shared characteristic of fast and low $V_{CE\ (sat)}$ miniBLOC IGBTs is the ability to survive short circuits. Transconduc-tance g_{fs} is chosen such that in the event of a short, when full bus voltage may appear across the still conducting device, collector current is limited to a value ensuring survival for at least 10 µs. This is sufficient for shut down to be implemented before destruction ensues.

It is of interest to compare chip area of a MOSFET miniBLOC to that of a comparably rated miniBLOC IGBT. Requiring two size 7 chips, a 1000 V IXTN15N100 MOSFET is rated 15 A at 25°C, whereas the 1000 V IXSN35N100U1 IGBT delivers 38 A from one size 7. This translates to more than double the current from half the area, a disparity resulting from physical laws relating area A to blocking voltage V.

For a MOSFET $\quad A = f\ (V^{2,6})$

For an IGBT $\quad A = f\ (V^{1.41})$

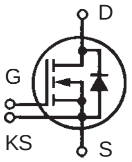
When V is doubled in a MOSFET, A increases sixfold to maintain the same $R_{DS\ (on)}$; in an IGBT the multiplier is a mere 2.7. The conclusion is inescapable that a high voltage IGBT (> 500 V) will always be less expensive than an equivalently rated MOSFET.

IXYS' range of FRED miniBLOCs consists of both 2x30 A, 2x60 A and 2x120 A diodes, with blocking voltages between 200 V and 1200 V. DSEI 2x30 product features an anti-parallel arrangement of the two individual chips insofar as the four external terminals are concerned, whereas the electrically identical DSEI 2x31 and higher current DSEI 2x61 series have a parallel configuration. The parallel layout facilitates printed circuit board and buswork design in many popular circuit architectures, SMPS secondary rectification for one.

FREDs differ from ordinary diodes in that minority carrier lifetime is controlled to minimize stored charge at the moment of commutation. A diode with stored charge cannot support reapplied reverse voltage until this charge is swept out via reverse recovery current. In most converter

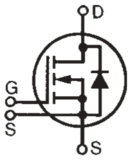
Table 1: miniBLOC product range

Standard Power-MOSFET



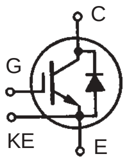
Type	V_{DSS} V	$I_{D(cont)}$ A	$R_{DS(on)}$ Ω
IXTN 79 N20	200	85	0.025
IXTN 36 N50	500	36	0.12
IXTN 15 N100	1000	15	0.6
IXTN 21 N100	1000	21	0.55

HiPerFET Power MOSFETs with Fast Intrinsic diode



Type	V_{DSS} V	$I_{D(cont)}$ A	$R_{DS(on)}$ Ω
IXFN 100 N07	70	200	0.006
IXFN 150 N10	100	150	0.012
IXFN 106 N20	200	106	0.020
IXFN 73 N30	300	72	0.045
IXFN 44 N50	500	44	0.12
IXFN 48 N50	500	48	0.10
IXFN 61 N50	500	61	0.075
IXFN 36 N60	600	36	0.18

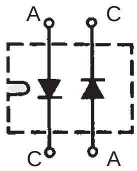
Insulated Gate Bipolar Transistors (IGBT) with ultrafast diode



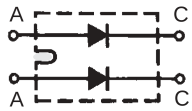
Type	V_{CES} V	I_C (A) $T_C = 25°C$	$T_C = 90°C$
IXSN 62 N60 U1	600	90	50
IXSN 35 N100 U1	1000	38	25
IXSN 52 N60 AU1	600	80	40
IXSN 35 N120 AU1	1200	70	35
IXSN 55 N120 AU1	1200	110	55
IXGN 200 N60A*	600	200	100

* without diode

Fast Recovery Epitaxial Diode (FRED)

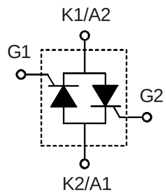


Typ	V_{RRM} V	I_{FAV} @ A	T_C °C	t_{rr} ns
DSEI 2x30-04C	400	2x30	85	35
DSEI 2x30-06C	600			
DSEI 2x30-10B	1000	2x30	50	50



DSEI 2x31-04C	400	2x30	85	35
DSEI 2x31-06C	600			
DSEI 2x31-10B	1000	2x30	50	50
DSEI 2x61-04C	400	2x60	70	35
DSEI 2x61-06C	600			
DSEI 2x61-10B	1000	2x60	50	50
DSEI 2x61-12B	1200	2x52		
DSEI 2x121-02A	200	2x123	70	35

AC Controller



Typ	V_{RRM} V	I_{RMS} $T_C = 85°C$ A	I_{TAVM} $T_C = 85°C$ A
MMO 62-12io6	1200	54	25
MMO 62-16io6	1600	54	25
MMO 75-12io6	1200	74	34
MMO 75-16io6	1600	74	34

applications this current appears as forward current in associated semiconductor switches as they turn on, creating substantial losses.

The use of FREDs optimized for lowest recovery current is a must if such losses are to be minimized. It is not enough, however, just to exhibit fast recovery; the nature of the transition from peak recovery current to zero is also critical. As stored charge decays, the FRED's junction impedance eventually starts to increase from virtually zero to a high value commen-surate with reverse blocking. Should this transition occur too abruptly, extreme values of di/dt generate overvoltages with high dv/dt across any stray inductance in the current loop. Such phenomena may cause device failure (of the FRED and/or other semiconductors) or circuit malfunction. An ideal FRED must blend very low recovered charge with "soft" transition of recovery current to zero. IXYS FREDs are optimized along these lines. Low voltage devices (200 V - 600 V suffix -C) recover in < 35 ns under JEDEC test conditions, while high voltage types (600 V - 1200 V suffix -B) are specified < 50 ns. Both varieties exhibit soft recovery. Commutation behaviour is also specified under severe conditions more akin to those in real life circuits than to JEDEC Standards.

Minimum size

The SOT-227B miniBLOC is a fully isolated compact power module, with total volume < 7 cm³. Its footprint, with respect to baseplate mounting screw centres and rectangular heatsink space, is compatible with metal-housed TO-3/TO-204 packages. When com-pared to earlier power modules, like TO-240s, the most striking features of the SOT-227B is its reduced height of only 12 mm between baseplate and upper terminal mounting planes (Fig.1). Beyond the obvious benefits of space savings, very important in modern high packing-density equipment like SMPS, this thinness results in a dramatic reduction in performance-degrading stray lead inductance. On the contrary, unlike discrete TO-204, TO-247 or TO-218s with similar low strays, the SOT-227B has the merit of electrical connections well separated from the (often grounded) heatsink. Electrical connections through holes in the heatsink likewise are unnecessary. This leads to comfortable safety margins with respect to potential isolation faults in time due to dirty environments.

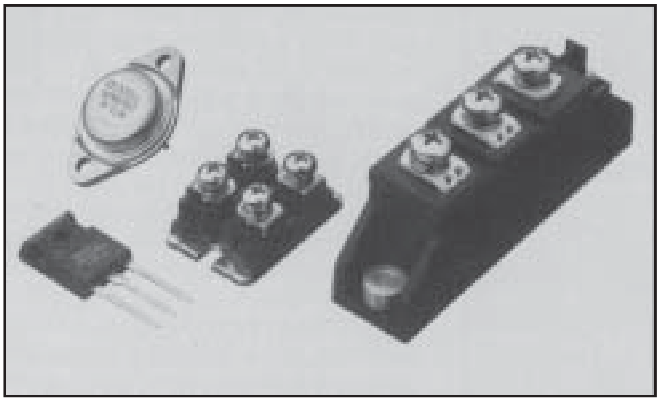


Fig. 1 miniBLOC, the alternative package between discretes and modules

Internal isolation

The SOT-227B package (Fig. 2) features an electrically isolated mounting plane, isolation being effected via an Al_2O_3 or an Aluminiumnitrite-substrate (AIN) ceramic substrate sandwiched between chips and baseplate. Isolation voltage is specified according to UL/VDE Standards at 2500 V_{RMS}/60 s or 3000 V_{RMS}/1 s.

Spacings between live terminals and between baseplate and terminals are generous; terminal-to-terminal strike distance through air is 4.5 mm with a surface creepage path of 9.5 mm, while terminal-to-baseplate strike and creep are each 9.5 mm. Such specifications translate to dependable operation over long periods of time. In particular, the risk of isolation failure is much less than in many power discretes, where strike and creep distances are marginal, and where external isolation via mica washers or similar is fragile and subject to damage and/ or contamination.

No external diodes needed

IGBT miniBLOCs incorporate FRED bypass diodes. Where circuit architectures demand bypass configurations, like the phase-legs in inverter AC motor drives, the use of FREDs is mandated by the need to reduce switching losses in both IGBTs and FREDs. As already mentioned, it is equally desirable that the FREDs recover gently, so as to minimize over voltages, steep wavefronts, and ringing (Fig. 3) [1]. Since these phenomena are related to stray circuit inductance as well as to high di/dt, it is clearly beneficial to minimize stray inductance along with di/dt. In a miniBLOC, stray inductance between the constituent parts is kept to a strict minimum by bonding the FRED chip adjacent to the IGBT on the same substrate. The fact that two active devices are packaged in one housing is of course attractive from a purely commercial standpoint!

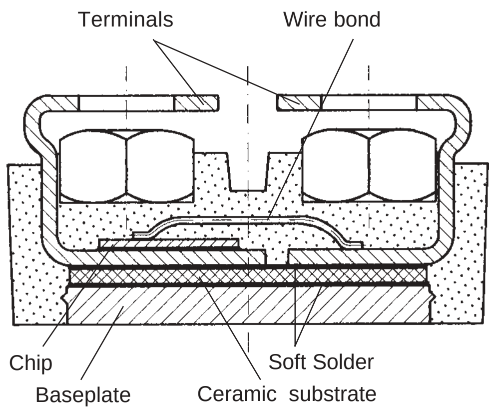


Fig. 2 Cross section of SOT-227B

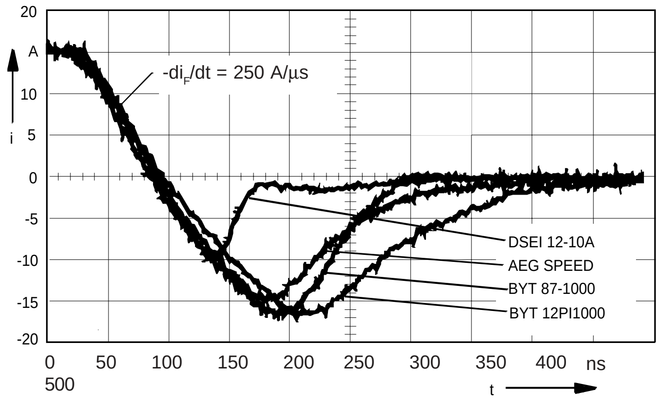


Fig. 3 Fast diode turn-off [1] (DSEI 12-10 A) features same FRED technology as in miniBLOC

International package

Industry Reference SOT-227B designates a generic package outline popularly known as the ISOTOP, a trademark of SGS/ THOMSON and Philips. IXYS' name for the package is miniBLOC.

Different ssuppliers are on the market with SOT-227B-package, so second-sourcing of most product variants is well assured. IXYS does not offer an SOT-227A version of the package (fitted with Faston terminals instead of M4 screws). This termination tends to be unsuitable for products capable of conducting very high currents at high frequencies.

The heart of the SOT-227B package is a solid copper baseplate on which is soldered a metallized ceramic substrate, usually of aluminium oxide (Al_2O_3) or aluminium nitride (AIN) (Fig. 4).

Better Cooling

The upper surface of the substrate is also metallized, but in a selective manner, to accommodate one or more copper heat spreading plates on which the silicon chips are soldered. The surfaces of all copper plates to be soldered are striated (longitudinally grooved) and brassed, to encourage void-free joints that are low in thermal resistance and resistant to thermal fatigue. Although ceramic insulators are not particularly good heat conductors per unit thickness, their overall thickness can be minimized without prejudicing isolation integrity, because the entire subassembly is subsequently over-moulded with a high-dielectric strength resin.

Presence of the relatively thick upper heat spreading plate also enhances thermal transfer, through elimination of hot spots beneath the chips. An overall 0.60 K/W junction to heatsink thermal resistance per size 7 chip compares favourably with similarly sized TO-247 discretes, and this without the fragility and elevated assembly costs endemic to TO-247 solutions. Depending on the number and size of chips, with Al_2O_3 substrate material the SOT-227B can dissipate up to 400 W at a case temperature of 25°C; with

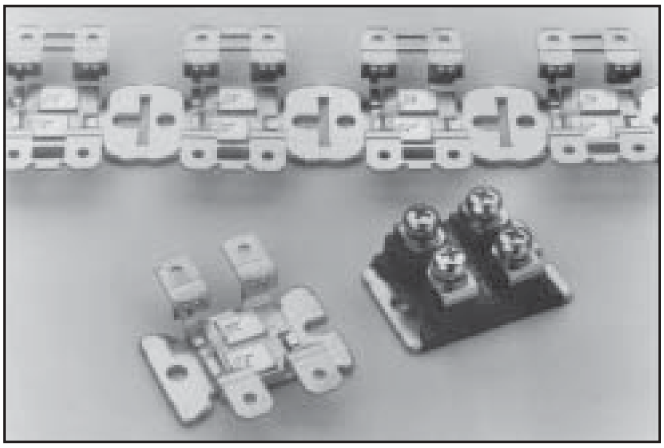


Fig. 4 Internal construction of SOT-227B

AlN, allowable dissipation is even higher (520 W).

Low stray inductance

In this era of MOSFET switching circuits with drain current di/dts routinely exceeding 1000 A/ms, the reduction of stray inductance in the leads between silicon chip and package terminals is of vital importance. Stray inductance in the internal drain lead, for example, can produce dangerous overvoltages that are unsuppressible by external means. At 1000 A/µs, an inductance of 100 nH, not uncommon in conventional "tall" module packages, will generate an overvoltage (Fig. 5).

E = L • di/dt = 100 nH • 1000 A/µs = 100 V

In a miniBLOC, internal lead inductance is less than 5 nH, limiting overvoltage to 5 V. Because parasitic inductance is not unique to the drain lead, but is also in the source path, the consequences of even minimal inductance here must be assessed. In a typical MOSFET or IGBT switching circuit a 10 - 15 V gate drive is normally specified. When this signal is returned to the driver via the external source terminal, any parasitic source inductance will inject degenerative feedback as the source current rises, slowing switching and increasing losses. Provision of a Kelvin-source circumvents this phenomenon in the miniBLOC. The Kelvin-source is a separate path from chip to another package terminal, to which the driver circuit return is connected; since this lead conducts no load current, negative feedback is inhibited and performance is unimpaired.

Low inductance packaging with Kelvin-source connection also enhances performance in miniBLOC Power MOSFETs, where two silicon chips are mounted in parallel. These features, allied with symmetrical placement of chips originating from the same wafer lot for matched $V_{GS(th)}$, g_{fs} etc., inhibit ringing, guarantee stability and ensure good dynamic current sharing. Damping is further improved through incorporation of a low value resistor in series with each internal gate lead.

Optimized low stray Capacitance

In a high speed switching power semiconductor, any capacitance between the silicon chip and grounded heatsink will couple Radio-Frequency-Interference (RFI), sometimes

Low stray inductance (< 5 nH)

a)

b)

c)

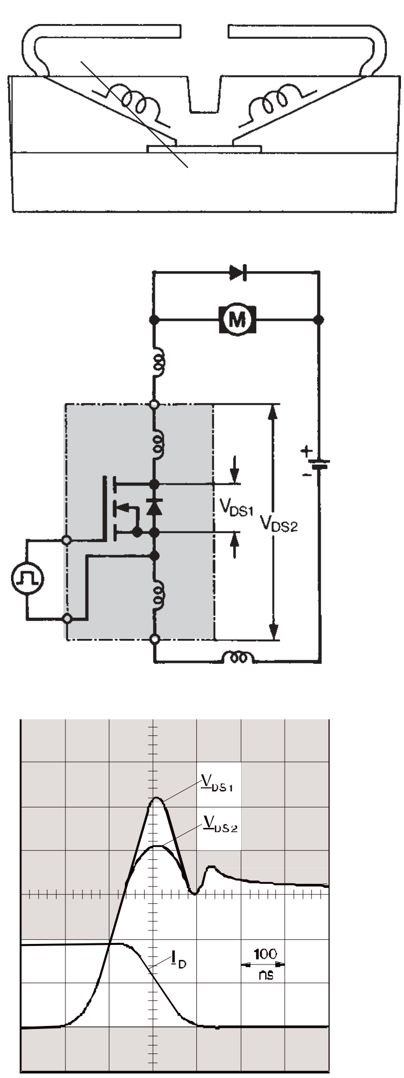
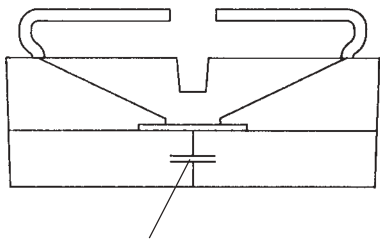


Fig. 5 Voltage overshoots due to stray lead inductance
a) internal stray inductance
b) simplified circuit with internal and external stray inductance
c) voltage overshoots on MOSFET chip (V_{DS1}) and main terminals (V_{DS2})



Low stray capacitance (< 45 pF)

Fig. 6 The miniBLOC package has anoptimized low stray capacitance < 45 pF

called EMI (Electro-Magnetic-Interference), from the floating electronic circuit to earth

$$i_{RFI} = C \cdot dv/dt$$

where i_{RFI} is the conducted noise current, C the stray capacitance and dv/dt the switching wavefront. Because efficiency considerations normally dictate the fastest possible switching, RFI can only be shrunk by limiting C. In a miniBLOC, with its relatively thick Al_2O_3 insulation layer, C < 45 pF, which is very low compared to the capacitance of the thin mica washers traditionally adopted to isolate TO-247 or TO-218 discrete packages (Fig. 6).

Common package for all functions

The miniBLOC package, with its ceramic isolator, elevated dissipation capability, four terminals and low parasitics, is extremely versatile. Because the substrate may be metallized to accommodate various circuit topologies, chip sizes and species, prospects for future product iterations are enormous. (Fig. 7) Supplementing today's Power MOSFETs, IGBTs and FREDs, products like back-to-back thyristor or IGBT pairs duplicating triac functions with better dv/dt, thyristor-diode phase legs for half controlled bridges, MOSFET/IGBT/FRED combinations for forward converters switched reluctance motor drives and dynamic braking are all feasible, to say nothing of Schottky combinations and mundane but useful products like single phase rectifier bridges. With such a wealth of product possibilities, the prospect of assembling complete power conversion equipments from one array of miniBLOCs sandwiched between a single grounded heatsink and single printed circuit board is very appealing. The photograph (Fig. 7) illustrates the internal layout of a state-of-the-art 230 V AC mains driven 1600 W/50 V DC SMPS featuring such a construction. Seven SOT-227Bs are incorporated -

- mains rectification/soft start (2 x thyristor/diode phase legs).
- power factor correction boost-converter (PowerMOSFET shunt switch and FRED boost diode).
- SMPS forward converter (Bipolar transistor).
- output rectifiers (2 x double FREDs).

Compact assemblies of this sort are both practical and economical, not only from initial cost, superior performance and long term reliability criteria, but for ease of maintenance; because miniBLOCs are easily removable from complex assemblies with a screwdriver, equipment repair is simple compared to separating multiple discrete power devices from a PCB by unsoldering.

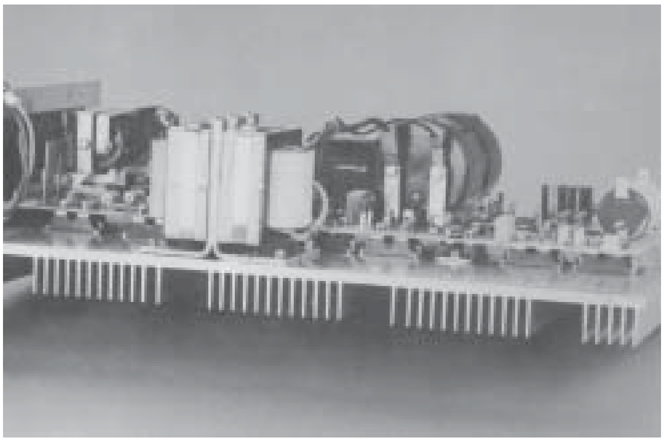


Fig. 7   1600 W/50 V DC SMPS -courtesy of Harmer & Simmons, Ilford, Great-Britain

Reference

[1] Heumann, K.: Impact of turn-off Semiconductor devices on power electronics, EPE Journal, Vol. 1 (1991), Nr. 3, pp 181 - 192