TECHSEM

Technical Information Techsem Module

1. Introduction

Techsem is the only publicly listed enterprise in China with more than 47 years of experience in the production of power electronic components. Techsem has expertise in all aspects of the production process, from wafer and chip processing to power device manufacturing. The power modules made by Techsem include various circuit topologies such as thyristors (MT and MTC Series) / rectifier diodes (MD and MDC Series), hybrid modules (MFC Series) and rectifier bridges (MDS Series). The output current range is from 26A to 570A and the maximum reverse voltage range of the modules is up to 3600V. Techsem is the leader in the Chinese power module market. Techsem products are widely used for metal smelting, motor drives, power supply, power transmission and distribution, railway transportation, machinery manufacturing, welding machines, chemical industry, renewable energy, and other applications in many industries.

1.1. Features

The packages of Techsem power modules are in full compliance with international standards, providing excellent versatility and substitutability to customers. All Techsem power modules have CE marking and comply with European RoHS directives. In addition, the thyristor modules, rectifier diode modules and hybrid modules have UL (file No. E321159) marking as well. The power modules are categorized according to chip type and circuit topologies as follows:

- Thyristor Module: including single thyristor (MT Series) and half bridge (MTC Series) circuits. Current rating is from 26A to 570A, voltage class is from 400V to 2500V. Depending on packaging size of the modules, there are different housings available:
  - MTC Series: 216F3 / 223F3 / 413F3 / 416F3;
  - MT Series: 417F2.

  For different customer habits, the different sequences of connection for the control connectors Gate (G) and Auxiliary Cathode (K) are offered: G1/K1，G2/K2 （216F3 / 223F3）and G1/K1, K2/G2 (216F3B / 223F3B). The typical applications for thyristor modules are AC/DC motor drives, rectifier devices, Softstarter, DC supply for PMW inverter, UPS, among others.

- Rectifier Diode Module: including single diode (MD Series) and half bridge (MDC Series) circuits. Current rating is from 26A to 570A, voltage class is from 400V to 2500V. Depending on packaging size of the modules, there are different housings available:
    - MDC Series: 216F3 / 223F3 / 413F3 / 416F3;
    - MD Series: 417F2.

  The typical applications for rectifier diode modules are AC/DC motor drive, rectifier devices, Soft start AC motor control, DC supply, Supplies for DC power equipment etc.
- Hybrid Module (Diode+Thyristor): MFC series with current rating from 26A to 570A. Voltage class is from 1200V to 2500V. Depending on packaging size of the modules, there are different housings like 216F3 / 223F3 / 413F3 / 416F3. The typical applications for hybrid modules are AC/DC motor drives, rectifier devices, soft start AC motor control, SVC, DC supply, UPS etc.
- Three Phase Rectifier Bridge: MDS series with current rating from 50A to 200A. Voltage class is from 800V to 2200V. Depending on packaging size of the modules, there are different housings like 218H5 / 219H5 / 221H5. The typical applications for hybrid modules are Supplies for DC power equipment, DC power supply for PWM inverter, inverter welding devices, Input rectifier for switch mode power supplies (SMPS) etc.

1.2. Topologies

For different applications, 7 different circuit topologies of Techsem power modules can be used. They are MTC / MFC / MT / MDC / MD / MDQ / MDS. Please refer to Fig.1.

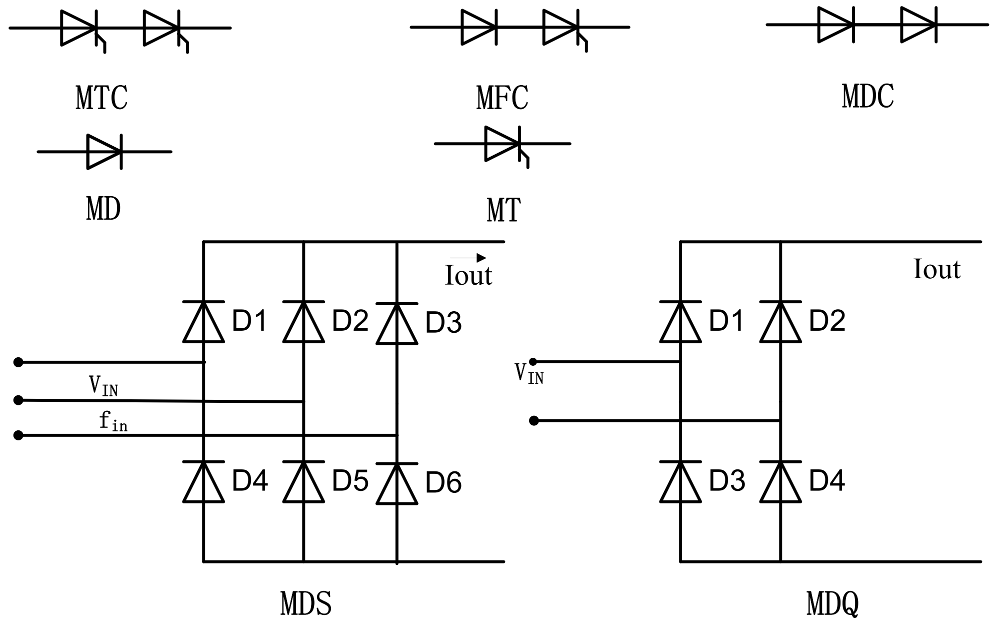


Fig.1 Different circuit topologies of Techsem modules

1.3. Housings

Depending on packaging size of the modules, 8 different housings are available. Please refer to Fig. 2.

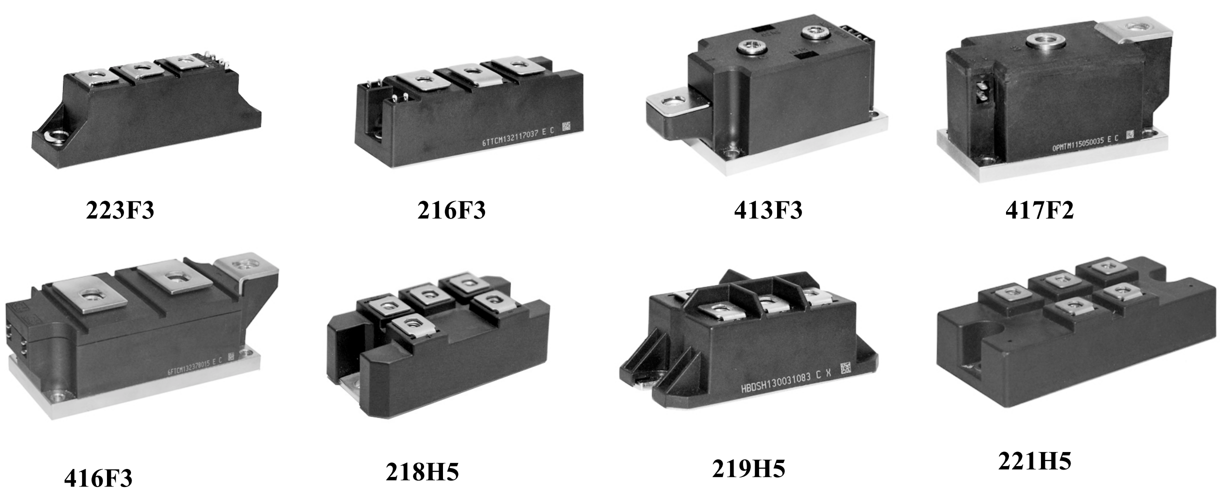


Fig.2 Different housings of Techsem modules

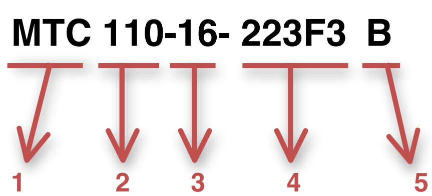
The size of the 8 different housings are indicated in the following table:

Case	*Length (mm)*	*Width (mm)*	*Height (mm)*
223F3	92	21	30
216F3	94	34	29.2
413F3	115	50	50
416F3	150	60	50.5
417F2	100	50	52
218H5	80	39.9	27.5
219H5	80	40	27.5
221H5	110	50	29

Fig. 3 The housing sizes of Techsem modules

For Techsem modules, standard tolerance of catalogue drawings is +/-0.5mm.

1.4. Type Designation



- 1: Circuit topology such as MT, MTC, MFC, MD, MDC and MDS
- 2: Rated current (I_{TAV} [A])
- 3: Voltage class, V_{DRM}/V_{RRM}= class×100 [V]
- 4: Housing type, please refer to Fig. 2
- 5: Option, with "B" means the sequence of the gate terminal (G) and auxiliary cathode terminal (K) is in order of G1/K1, K2/G2.

2. Quality-Control Principles

To ensure the high quality level of the Products, Techsem adheres to the following principles:

2.1. Techsem guarantees that all business processes, including product design and production, are in accordance with the requirements of the ISO 9001:2008 Quality Management System.

2.2. Techsem guarantees that In-process inspections and product testing will be carried out throughout the production process.

2.3. In-process inspection includes assessment of the appearance and parameters of the procedures from the wafer diffusion stage to chip and module / capsule assembly.

2.4. Product testing involves four test categories:

Group A: Routine Testing for all manufactured devices

Group B: Lot Control Testing

Group C: Qualification Maintenance

Group D: Qualification Approval Testing

2.4.1 Group A Testing:

Techsem guarantees 100% testing with the following parameters for all products before delivery:

Parameters	T_j	Reference Documents	Inspection Requirements
V_{DRM} V_{RRM}/ I_{DRM} I_{RRM}	25°C/ T_{jm}	IEC60747-6, IEC60747-2 Individual test specification per article	100%
dv/dt	T_{jm}	IEC60747-6 Individual test specification per article	100%
Qrr trr (on request)	T_{jm}	IEC60747-6, IEC60747-2 Individual test specification per article	100%
V_{TM} /V_{FM}	25°C/ T_{jm}	IEC60747-6, IEC60747-2 Individual test specification per article	100%
I_{GT} V_{GT} I_H	25°C	IEC60747-6 Individual test specification per article	100%
tq (on request)	T_{jm}	IEC60747-6 Individual test specification per article	100%
V_{iso} (for Isolated Module)	25°C	AC 50Hz RMS 1min/1s Individual test specification per article	100%

Fig. 4 Group A Testing

2.4.2 Group B Testing:

To ensure the quality reliability, Techsem regularly carries out spot testing (Group B Testing). The purpose of the testing shall be the inspection of AC blocking voltage of the products.

Examination or Test		Reference Documents		
Sub-group	Test Category	IEC & Internal Standard	Condition	Note
B1	Endurance: AC blocking	IEC60747-6 V	24 h at T_{vj} max Sine wave 50 Hz V_D = 0.7...0.8 V_{DRM}	Note1

Fig. 5 Group B Testing

2.4.3 Group C and D Testing:

In addition, Techsem carries out annual Group C testing to evaluate the long-term stability of the products.

For new products or modified production processes, Techsem carries out Group D testing to confirm the appraisal before release of the products.

Group C Testing				
Examination or Test		**Reference Documents and Conditions**		
Sub-group	**Test Category**	**IEC & Internal Standard**	**Conditions**	**Notes**
C1a	I_L	IEC 60747-6	T_j=25°C	
	I_H	IEC 60747-6	T_j=25°C	
C1c	I_{TSM} /I_{FSM}	IEC 60747-6	T_{jm} 10ms half Sine wave, V_{RM}＝0.6V_{RRM}	
C1d	R_{jc}	IEC 60747-6		
C2	V_{GD}	IEC 60747-6	T_{jm}，V_D＝V_{DRM}	
C3	V_{RGM}	IEC 60747-6	T_j=25°C	
C4	P_{GM}	IEC 60747-6	T_j=25°C	
C5	di/dt	IEC 60747-6	T_{jm}，V_D= 0.5V_{DRM}，I_{TM}≥2$I_{T(AV)}$，t_r≤0.5 μs，I_{GM}=（3～5）I_{GT}，tw≥20 μs，50 Hz，60 s	
C6	Endurance: AC blocking	IEC 60747-6	1000 h at Tvj max Sine wave 50 Hz V_D = 0.7...0.8 V_{DRM}	Note 1
C7	Endurance: Storage at high temperature	IEC600 68-2-2 1031.4 7021 B-10	1000h at Tstg max	Note 1
C8	Sealing (Capsule package only)	IEC 60068-2-17	Helium mass spectrum	

Fig. 6 Group C Testing

Group D Testing:				
Examination or Test		Reference Documents and Conditions		
Sub-group	Test Category	IEC & Internal Standard	Conditions	Notes
D1	Endurance: Storage at low temperature	IEC60068-2-1 Aa7021 B-12	500 hours at Tstgmin	Note1
D2	Endurance: Thermal cycling load (Thermal fatigue)	IEC60747-6 IV, 41037.1 7021 B-18	ΔT_{vj} = 80°C ... 100°C 10000 cycles	Note1
D3	Thermal Cycling	IEC60068-2-14 Test Na	Tstgmax~Tstgmin 10 cycles	Note1
D4a	Shock	IEC60068-2-27 Ea2016.2 7021 A-7	Internal Standard	Note2
D4b	Vibration (sinus)	IEC60068-2-6 Fc2056 7021 A-10	Internal Standard	Note2
D5	Salt mist	IEC60068-2-11 Ka1046.2	35°C, 5% NaCl, 7 days	Note 3
D6	Robustness of terminations	IEC60068-2-212036.3A 7021 A-11	Tension, 40 N, 10s	

Fig. 7 Group D Testing

Testing methods and test materials can differ among various products and applications. For details, please refer to the product specifications or datasheets.

Notes:

1) Failure criteria for Diodes: I_{RRM} ($T_{vj\ max}$) < 1.1 USL

V_{FM} < 1.1 USL

Failure criteria for Thyristors: I_{RRM}, I_{DRM} ($T_{vj\ max}$) < 1.1USL

I_{GT}, $V_{GT\ (25°C)}$ < 1.1 USL

V_{TM} ($T_{vj\ max}$) < 1.1 USL

2) Failure criteria for all devices: Integrity of package materials, wafers, sealing (for capsule types), lead connections.

The device must meet requirements listed under note1.

3) Failure criteria for all devices: no significant corrosion.

3. Application

3.1 Reserve Voltage Selection

In Fig. 8 it shows the relation beween the input line voltage (AC) and the recommended repetive peak off-state and reverse voltage(V_{DRM}/V_{RRM}).

Input Line Voltage (V)	V_{DRM}/V_{RRM} (V)
60	200
125	400
250	800
380	1200
400	1400
440	1400
460	1600
500	1600
575	1800
660	2000
690	2200

Fig. 8 Recommended Reverse Voltage

Note: The maximal permissible continuous voltage on a diode V_R or SCR V_D/V_R should be $0.7V_{DRM}/V_{RRM}$

3.2 Overvoltage Protection

It is well known that semiconductor components are sensitive to overvoltage. The voltage surges exceed the rated voltage indicated in the datasheet can destroy the components. Therefore, the components must be protected from all possible overvoltage. The most popular methods for overvoltage protection are:

- Using resistors and capacitors directly parallel to the single switches.
- Using snubber circuit at AC side.
- Using varistors.
- Using snubber circuit based on silicon avalanche diode.

3.2 Overcurrent Protection

An increased current load can be caused by an unforeseen rapid current increase or by an unexpected change in cooling conditions. To protect the semiconductor components from current increase, the following devices can be used:

- Power circuit breakers or fuses
- Protection by driver unit

As protective devices for malfunctions in the cooling device, the following possibilities can be considered:

- Wind van relays to trigger a protective component in case of malfunctions
- Water flow monitor for water-cooled system

3.3 Determination of gate trigger voltage V_{GT} and gate trigger current I_{GT}

A gate trigger voltage V_{GT} and a gate trigger current I_{GT} indicates the minimum voltage or current to switch on a thyristor under the normal room temperature. The dynamic characteristics in on-state of the thyristor e.g. switch-on time, switch-on losses etc. are strongly impacted by the intensity of the gate trigger signals. To ensure the good switching characteristics it is recommended to trigger with stronger signals than the threshold values. Especially in case of low temperature application, the following trigger values shall apply: Current pulse amplitude$\geq 4 \sim 10 I_{GT}$, Pulse rising time$\leq 1\mu s$.

3.4 Series connection of rectifier diodes or thyristors

In order to achieve higher blocking voltage, diodes or thyristors can be connected in series. It is important to ensure homogenous voltage distribution in all diodes or thyristors. The common solutions are using parallel resistors in blocking state and using parallel RC circuit during the commutation. The voltage on each diode or thyristor should be at least 10% lower than for individual operation.

3.5 Parallel connection of rectifier diodes

The biggest challenge for parallel diode circuit is to achieve homogenous current distribution. To do so, the electric circuit layout should be optimized with consideration of similar connection points, wiring and wiring length. The diodes with similar characteristics in forward losses should be used for parallel connection. It is recommended to operate the parallel diodes with no more than 80% of the maximum rated mean forward current.

3.6 Parallel connection of thyristors

Also here is essential to ensure homogenous current distribution. For this purpose, pre-selected thyristors with similar characteristics in forward voltage should be used. Besides the aforementioned optimization of the electric layout, steeply rising trigger pulses with sufficient amplitude (refer to 3.3) is also necessary. No more than 80% of the maximum rated mean forward current should be loaded on each thyristor.

4. Technical Parameters

In the following paragraphs detailed explanation of electrical parameters in the datasheet will be given.

4.1 Mean Forward Current $I_{F(AV)}$ (Diode) / Mean On-state Current $I_{T(AV)}$ (Thyristor)

This refers to the maximum average current that the diode/thyristor is able to conduct in forward-bias mode under the defined heat sink temperature T_{HS} or case temperature T_C. This value depends on the current characteristics, the current conduction angle, and the cooling conditions. Thus, the maximum current represents the upper limit of junction temperature. Therefore, current overload is not permissible under normal operation. With consideration of changes in cooling conditions and environmental temperatures, it is recommended that the diode/thyristor operate at no more than 80% of the maximum rated mean forward current. On the datasheet, the relation of $I_{F(AV)}$ / $I_{T(AV)}$ to the heat sink temperature T_{HS} or case temperature T_C is indicated so that the suitable device for certain current can be determined.

4.2 Surge Forward Current I_{FSM} (Diode) / I_{FSM} (Thyristor)

This refers to the maximum permissible peak value of a single half sine wave 50Hz current pulse (10ms). These values on the datasheet are specified at turn-on at maximum permissible junction temperature with 80% of V_{RRM} (repetitive peak reserve blocking voltage). The number of withstanding of surge forward current during the lifetime of a device is limited. Current overload should be avoided if possible.

4.3 Peak Load Integral i^2t

The peak load integral can be calculated from the surge forward current $I_{T(F)SM}$ as follows:

$$\int_0^{t_{hw}} i_{FS}^2 \, dt = I_{FSM}^2 \cdot \frac{t_{hw}}{2}$$

t_{hw} represents the duration of the half sine wave under I_{FSM}. The maximum rated $\int i^2 dt$ value serves to determinate short circuit protection.

4.4 Repetitive Peak Off-state Voltage V_{DRM} / Repetitive Peak Reverse Voltage V_{RRM}

V_{DRM} is the maximum value of repetitive voltages in the forward off-state direction, including all repetitive peak voltages.

V_{RRM} is the maximum permissible instantaneous value of repetitive voltages in reverse direction, including all repetitive peak voltages.

These values should not be exceeded in any application.

4.5 Peak Value of Reverse Drain Current I_{DRM} / Peak Reverse Recovery Current I_{RRM}

These values are determined as off-state or reserve leakage currents at the V_{DRM} or V_{RRM} on the device under the maximum permissible junction temperature.

4.6 Threshold Voltage V_{TO}

V_{TO} is the voltage at the point of crossover between an approximation line of the forward characteristic and the voltage axis.

4.7 Forward Slope Resistance r_F

The equivalent line is an approximation for the on-state characteristic of a thyristor
or a diode to calculate the on-state power dissipation. The value of r_F is calculated from the rate of increase of the equivalent line. To calculate the forward power dissipation, the following formula is used $V_F = V_{TO} + r_F \times i_F$.

4.8 Forward Peak Voltage (Diode) V_{FM} / On-state Peak Voltage V_{TM} (Thyristor)

The values represent the voltages at the peak forward current I_{FM} (diode) or the peak on-state current I_{TM} (thyristor). They directly reflect the on-state characteristics and impact the forward current load of the device. The forward (on-state) peak voltage can be represented approximately by the threshold voltage and slope resistance: $V_{TM} = V_{TO} + r_T \times I_{TM}$; $V_{FM} = V_{FO} + r_F \times I_{FM}$.

4.9 Current Commutate Turn-off Time t_q (Thyristor)

This value represents the time interval between the instant when the decreasing on-state current passes through zero and the earliest reapplication of off-state voltage, after which the thyristor does not turn on again. The measured value of t_q depends on the applicable testing conditions. The testing conditions at Techsem are as follows:

- On-state peak current $I_{TM} = I_{TAV}$ of the device
- Critical rate of rise of on-state current di/dt = -20A/µs
- Rate of rise of reapplication voltage dv/dt = 30A/µs
- Reserve voltage $V_R = 50V$
- Junction temperature $T_j = T_{jm}$

4.10 Critical Rate of Rise of On-state Current di/dt

On the datasheet, this value is indicated as the maximum rate of rise of on-state current without damaging the thyristor. The value can be strongly impacted by the gate trigger conditions. Therefore, it is recommended to use stronger trigger signals such as current pulse amplitude ≥4～10 x I_{GT} or pulse rising time ≤1µs.

4.11 Critical Rate of Rise of On-state Voltage dv/dt

This value represents the maximum rate of rise of the on-state voltage at which the thyristor is not triggered. On the Techsem datasheet, the minimum values of dv/dt are given for all thyristors. Special requirements pertaining to the value of dv/dt are met for certain applications.

4.12 Gate Trigger Voltage V_{GT}

V_{GT} is the voltage that occurs across the gate terminal and cathode. At the specified gate voltage, all thyristors will trigger. The V_{GT} value indicates the voltage across the main terminals and the junction temperature. The gate trigger voltage decreases with increasing junction temperature and is thus specified at 25^{o}C.

4.13 Thermal Resistance Junction to Case $R_{th(j-c)}$

The thermal resistance between chip and module case is an important parameter representing the heat dissipation capability of the device. The value also indicates the on-state characteristics. On the Techsem datasheet, the thermal resistance of capsule components with double-sided cooling and the value for one-sided cooling of power modules are given. The values of capsule devices can be ensured only when the device is assembled on the heat sink with the mounting force indicated on the datasheet.

4.14 Isolation Test Voltage V_{iso}

The insulation voltage of the power modules is a guaranteed value for the insulation between the terminals and the base plate. The $\mathbf{V_{iso}}$ specified on the Techsem datasheet is the effective value of a 50Hz AC voltage with the test duration of 1 minute for each module. For the test duration of 1 second, the test voltage will be 20% higher.

5 Mounting and Assembly Instructions

To ensure good thermal contact between power modules and heat sink, the following requirements on the contact surface of heat sink shall be fulfilled:

Roughness R_Z<10µm and Unevenness <50µm over a distance of 100mm.

Before mounting on to the heat sink, a thin layer of thermal paste (app. 50µm) shall be painted on the baseplate of the module. In order to coat the layer evenly, it is recommended to use a hard rubber roller.

To guarantee a good contact between the module and the main bus bar, and to avoid any damage at the module during the assembly, it is necessary to use the assembly tools with torque measurement such as torque wrench. The torque for assembly can be set as follows:

Screw Size (mm)	M5	M6	M8	M10	M12
Torque (Nm)	4	6	12	12	14

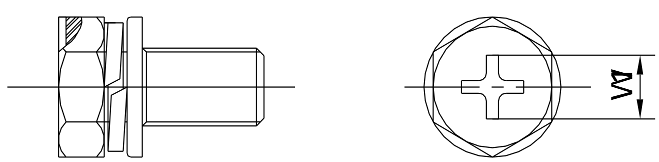
Fig. 9 screw size and torque

Over force shall be avoided during the assembly process. The torque tolerance shall be limited to 20%.

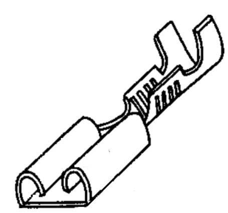
6 Accessories

Housing Type	223F3	216F3	413F3	416F3	417F2	218H5	219H5	221H5
Screw size and quantity	M5×10 3 pcs.	M6×12 3 pcs.	M8×16 3 pcs.	M10×20 3 pcs.	M10×20 2pcs.	M5×10 4 pcs. （MDQ） 5 pcs. （MDS）	M5×10 4 pcs. （MDQ） 5 pcs. （MDS）	M5×10 4 pcs. （MDQ） 5 pcs. （MDS）
Gate plug-in connector and quantity	2.8×0.8 4 pcs. (MTC) 2 pcs. (MFC)	2.8×0.8 4 pcs. (MTC) 2 pcs. (MFC)	2.8×0.8 4 pcs. (MTC) 2 pcs. (MFC)	2.8×0.8 4 pcs. (MTC) 2 pcs. (MFC)	2.8×0.8 2 pcs. (MT)			

Fig. 10 screws and gate connector needed for module assembly



Screw type	M5×10	M6×12	M8×16	M10×20
W1(mm)	4.5	5.5	8.5	9



Gate plug-in connector：2.8×0.8

Fig. 11 Schematic of screws and plug-in gate connector

7 Packaging

7.1. Marking on Power Modules

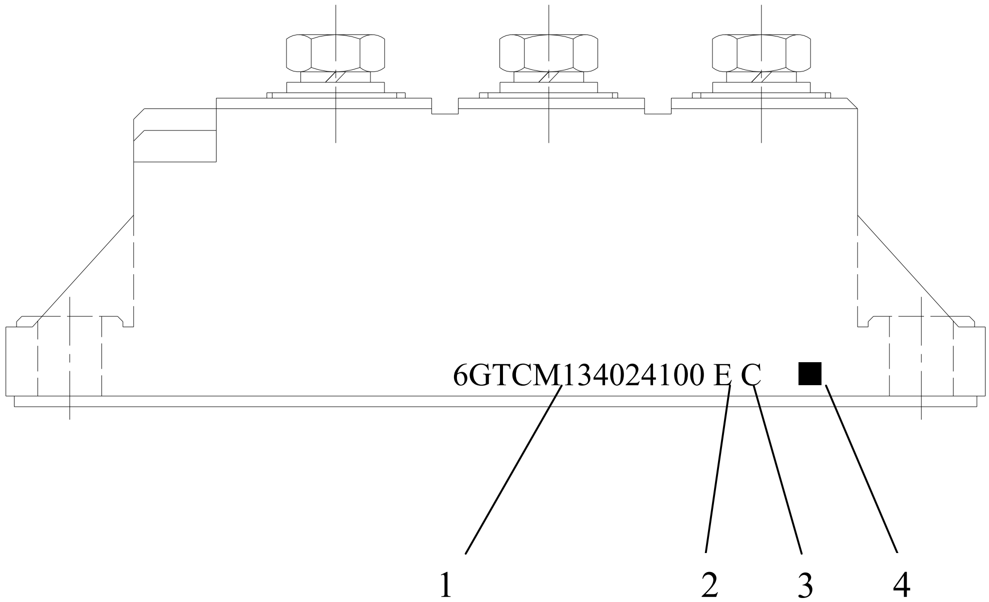


Fig. 12 One side view of a power module

1: Housing type code (6G) / Topology code (TC) / Manufacturing lot No. (M134021) and number of the module in the batch;

2: Voltage class code;

3: Gate range code;

4: Matrix code (includes the above data).

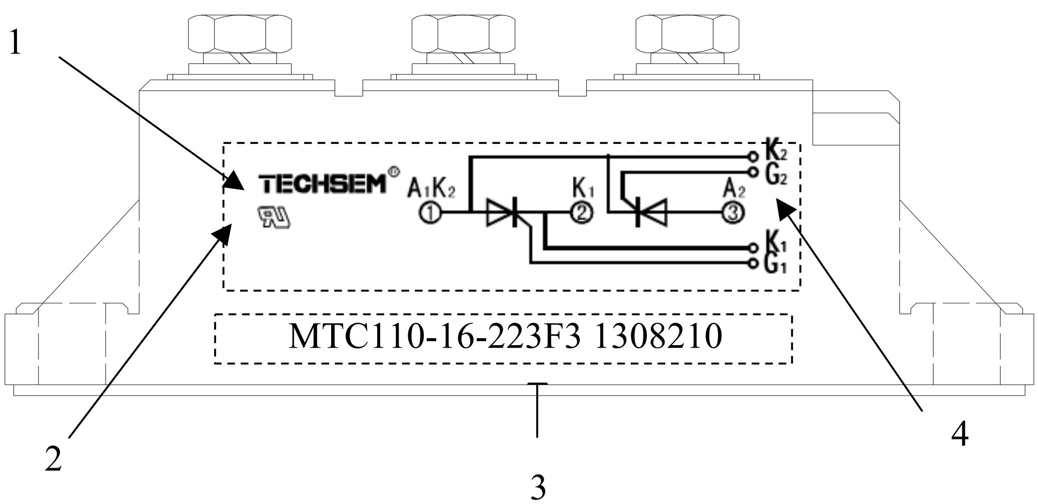


Fig. 13 The other side view of a power module

1: Techsem Logo;

2: UL Mark;

3: Module type / Voltage class / housing type and ship lot number;

4: Circuit topology.

7.2. Packaging box

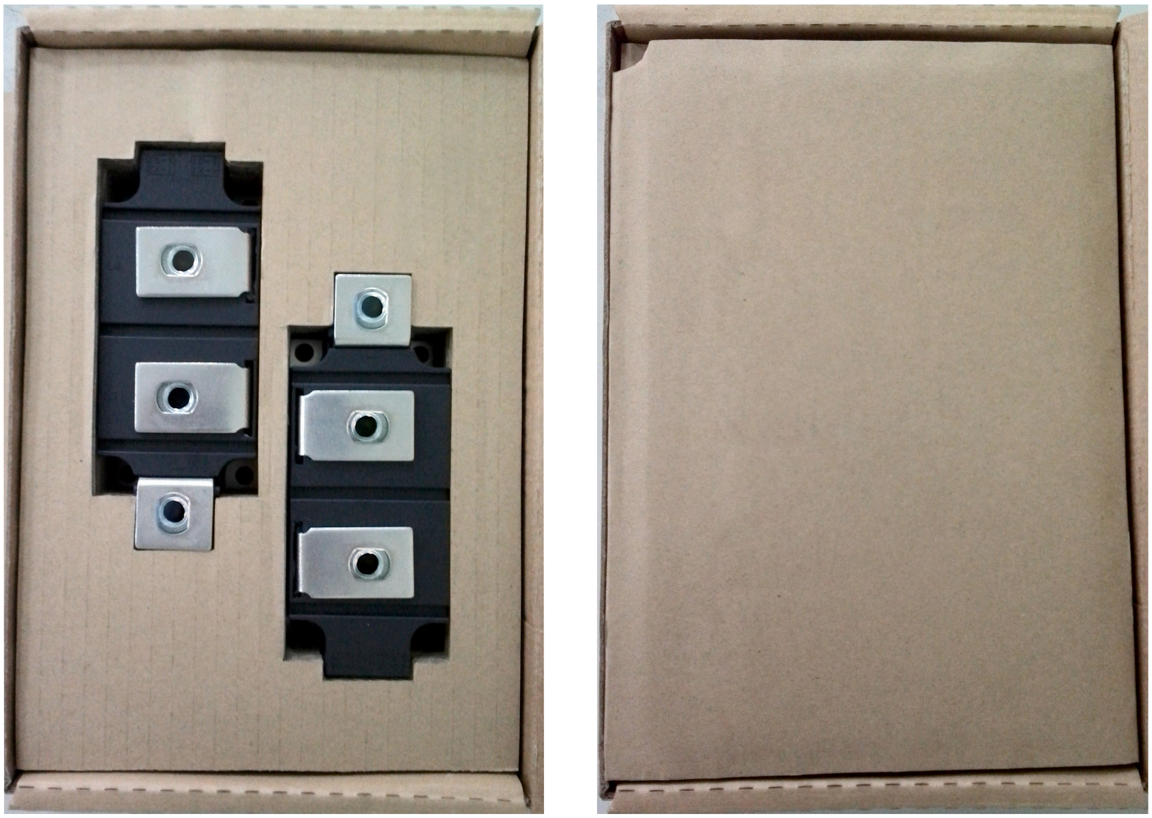


Fig.14 Standard Packing boxes for TECHSEM modules

Circuit Topology	Housing Type	Minimum Package Quantity (piece)
MTC / MDC / MFC	223F3	12
MTC / MDC / MFC	216F3	8
MTC / MDC / MFC	413F3	3
MTC / MDC / MFC	416F3	2
MTC / MDC / MFC	417F2	3
MDS	218H5 and 219H5	12
MDS	221H5	3

Fig.15 Quantities per package