中国中车 CRRC

**TM600FF12S3-F3A02**

**六单元 SiC MOSFET 模块 Six-Pack SiC MOSFET Module**

产品数据手册 Product Datasheet 版本 Ver 24.03

**初版 Preliminary**

## 关键参数 Key Parameters

| | | | |
|---|---|---|---|
| $V_{DSS}$ | | 1200 | V |
| $R_{DS(on)}$ | Typ. | 2.0 | mΩ |
| $I_D$ | Max. | 600 | A |
| $I_{DM}$ | Max. | 1200 | A |

## 典型应用 Typical Applications

- 电动汽车 Automotive Applications
- 混合动力/纯电动车 Hybrid/Electrical Vehicles
- 电机驱动 Motor Drives

## 特点 Features

- 铜针翅基板 Cu Pin-fin Baseplate
- 低开关损耗 Low Switching Losses
- 低反向恢复损耗 Low Reverse Recovery Loss
- 低感设计 Low Inductive Design
- $Si_3N_4$ 衬板 $Si_3N_4$ AMB Substrate

## 电路结构 Circuit Configuration

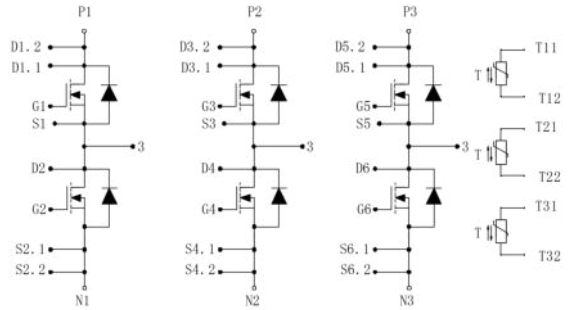



图 1.电路结构

Fig. 1 Circuit configuration

## 模块外形 Module Appearance

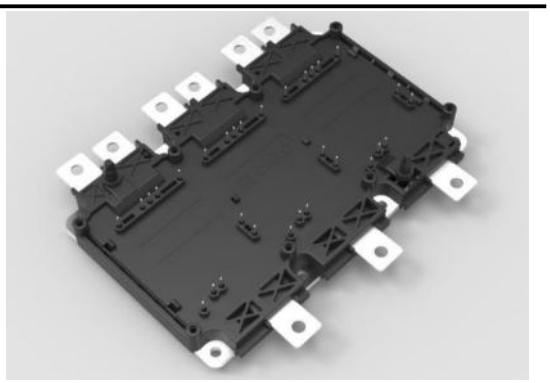


图 2. 模块外形

Fig. 2 Module appearance

## 模块标签说明 Module Label Code Instruction

| 数据位置 Data position | 数据内容 Content of data |
|---|---|
| 1--8 | 模块批次号 Module batch number |
| 9--12 | 模块序列号 Module serial number |

## 最大额定值 Absolute Maximum Ratings

| 符号 Symbol | 参数名称 Parameter | 测试条件 Test Conditions | 数值 Value | 单位 Unit |
|---|---|---|---|---|
| $V_{DSS}$ | 漏源极电压 Drain-source voltage | $V_{GS}$ = 0V, $T_C$= 25 °C | 1200 | V |
| $V_{GSSmax}$ | 栅源电压 Gate-source voltage | $T_C$= 25 °C | -8/+22 | V |
| $V_{GSSop}$ | 栅源电压 Gate-source voltage | $T_C$= 25 °C | -4/+18 | V |
| $I_D$ | 额定漏极电流 Rating drain current | $T_F$= 70 °C， $T_{vj\ max}$ = 175°C | 600 | A |
| $I_{DM}$ | 漏极峰值电流 Peak drain current | $t_P$=1ms | 1200 | A |
| $P_{max}$ | 晶体管部分最大损耗 Max. transistor power dissipation | $T_F$=70 °C, $T_{vj\ max}$=175°C | 1050 | W |
| $I^2t$ | 二极管 $I^2t$ 值 *Diode* $I^2t$ | $V_R$=0V,$t_p$=10ms,$T_{vj}$=175℃ | 60 | $kA^2s$ |
| $V_{isol}$ | 绝缘电压(模块) Isolation voltage – per module | 短接所有端子，端子与基板间施加电压 ( Connected terminals to baseplate), RMS,f=0 Hz,t=1 sec ,$T_C$= 25 °C | 4200 | V |

## 热和机械数据 Thermal & Mechanical Data

| 参数 Symbol | 说明 Explanation | 值 Value | 单位 Unit |
|---|---|---|---|
| 爬电距离 Creepage distance | 端子-散热器 Terminal to heatsink | 9 | mm |
| | 端子-端子 Terminal to terminal | 9 | mm |
| 绝缘间隙 Clearance | 端子-散热器 Terminal to heatsink | 4.5 | mm |
| | 端子-端子 Terminal to terminal | 4.5 | mm |
| 相对漏电起痕指数 CTI (Comparative tracking index) | | ＞200 | |

## 热和机械数据 Thermal & Mechanical Data

| 符号 Symbol | 参数名称 Parameter | 测试条件 Test Conditions | 最小值 Min. | 典型值 Typ. | 最大值 Max. | 单位 Unit |
|---|---|---|---|---|---|---|
| $R_{th(J-F)\ MOSFET}$ | MOSFET 热阻 Thermal resistance –MOSFET | 冷却液：50%乙二醇溶液；△V/△t=10 dm³/min； $T_F$ = 60 °C Cooling Fluid：50% water / 50% ethylene glycol；△V/△t=10 dm³/min； $T_F$= 60 °C | | 96 | 100 | K / kW |
| △$P$ | 冷却液流阻 Pressure drop in cooling circuit | 冷却液：50%乙二醇溶液；△V/△t=10 dm³/min； $T_F$ = 25 °C Cooling Fluid：50% water / 50% ethylenglycol；△V/△t=10 dm³/min； $T_F$= 25 °C | | 68 | | mbar |
| $P$ | 冷却液最大压力 Maximum pressure in cooling circuit | | | | 2.5 | bar |
| $T_{vj\ op}$ | 工作结温 Operating junction temperature | | -40 | | 175 | °C |
| $T_{stg}$ | 存储温度 Storage temperature range | | -40 | | 125 | °C |
| $M$ | 安装力矩 Screw torque | 安装紧固用 - M4 Mounting – M4 | 1.8 | 2.0 | 2.2 | Nm |
| | | PCB 安装用 PCB Mounting | 0.55 | 0.6 | 0.65 | Nm |

## 热敏电阻数据 NTC-Thermistor Data

| 符号 Symbol | 参数名称 Parameter | 测试条件 Test Conditions | 最小值 Min. | 典型值 Typ. | 最大值 Max. | 单位 Unit |
|---|---|---|---|---|---|---|
| $R_{25}$ | 额定电阻值 Rated resistance | $T_C$ = 25 °C | | 5 | | kΩ |
| △$R/R$ | $R_{100}$ 偏差 Deviation of $R_{100}$ | $T_C$ = 100 °C, $R_{100}$=493Ω | -5 | | 5 | % |
| $P_{25}$ | 耗散功率 Power dissipation | $T_C$ = 25 °C | | | 20 | mW |
| $B_{25/50}$ | $B$ -值 $B$ -value | $R_2 = R_{25} \exp [B_{25/50}(1/T_2 - 1/(298.15\ K))]$ | | 3375 | | K |
| $B_{25/80}$ | $B$ -值 $B$ -value | $R_2 = R_{25} \exp [B_{25/80}(1/T_2 - 1/(298.15\ K))]$ | | 3411 | | K |
| $B_{25/100}$ | $B$ -值 $B$ -value | $R_2 = R_{25} \exp [B_{25/100}(1/T_2 - 1/(298.15\ K))]$ | | 3433 | | K |

## 电特性值 Electrical Characteristics

除非特别声明，否则 $T_C$= 25 °C　　$T_C$= 25 °C unless otherwise stated

| 符号 Symbol | 参数名称 Parameter | 条件 Test Conditions | 最小值 Min. | 典型值 Typ. | 最大值 Max. | 单位 Unit |
|---|---|---|---|---|---|---|
| $I_{DSS}$ | 零栅压漏极电流 Zero gate voltage drain current | $V_{GS}$ = 0V,$V_{DS}$ = $V_{DSS}$ | | | 100 | μA |
| | | $V_{GS}$ = 0V, $V_{DS}$ = $V_{DSS}$, $T_{vj}$ =150 °C | | | 500 | μA |
| | | $V_{GS}$ = 0V, $V_{DS}$ = $V_{DSS}$, $T_{vj}$ =175 °C | | | 1000 | μA |
| $I_{GSS}$ | 栅极漏电流 Gate leakage current | $V_{GS}$ = -8/+22V, $V_{DS}$ = 0V | | | 500 | nA |
| $V_{GS(th)}$ | 栅极-源极阈值电压 Gate threshold voltage | $I_D$ = 80mA, $V_{GS}$ = $V_{DS}$ | 2 | 2.7 | 3.4 | V |
| $R_{DS(on)}$ (*1) | 漏极-源极通态电阻 Drain-source on-state resistance | $V_{GS}$ =18V, $I_D$ = 600A | | 2.00 | | mΩ |
| | | $V_{GS}$ =18V, $I_D$ = 600A, $T_{vj}$ = 150 °C | | 2.70 | | mΩ |
| | | $V_{GS}$ =18V, $I_D$ = 600A, $T_{vj}$ = 175 °C | | 3.07 | | mΩ |
| $g_{fs}$ | 跨导 Forward transconductance | $V_{DS}$ =20V, $I_D$ = 600A | | 350 | | S |
| $V_{SD}$(*1) | 二极管正向电压 Diode forward voltage | $I_{SD}$ = 600A, $V_{GS}$(*2) = -4V | | 5.7 | | V |
| | | $I_{SD}$ = 600A, $V_{GS}$ = -4V, $T_{vj}$ = 150 °C | | 5.3 | | V |
| | | $I_{SD}$ = 600A, $V_{GS}$ = -4V, $T_{vj}$ = 175 °C | | 5.1 | | V |
| $I_{SC}$ | 短路电流 Short circuit current | $T_{vj}$ = 175°C, $V_{DD}$ =800V, $V_{GS}$≤18V, $t_p$≤TBDμs, $V_{DS(max)}$ = $V_{DSS}$ – $L$(*3)×di/dt, IEC 60747-8 | | TBD | | A |

**注意：**
**Note:**

1.(*1) 表示该参数的测试点为辅助母排端子( (*1) indicates it is measured at the auxiliary busbar terminal),

2.(*2) 图 13 中也提供了 $V_{GS}$ 为 0、15V 条件下的 $V_{SD}$. ( (*2) $V_{SD}$ with $V_{GS}$=0、15V is also provided in figure 13.)

3.(*3) 表示 $L$ 是电路杂散电感加上 $L_{sDS}$ ( (*3) indicates $L$ is the circuit stray inductance plus $L_{sDS}$).

## 电特性值 Electrical Characteristics

除非特别声明，否则 $T_C$= 25 °C　　$T_C$= 25 °C unless otherwise stated

| 符号 Symbol | 参数名称 Parameter | 条件 Test Conditions | 最小值 Min. | 典型值 Typ. | 最大值 Max. | 单位 Unit |
|---|---|---|---|---|---|---|
| $C_{iss}$ | 输入电容 Input capacitance | $V_{DS}$ = 600V, $V_{GS}$ = 0V, $f$ = 100kHz | | 31 | | nF |
| $Q_g$ | 栅极电荷 Gate charge | -4/+18V | | 1.47 | | μC |
| $C_{rss}$ | 反向传输电容 Reverse transfer capacitance | $V_{DS}$ = 600V, $V_{GS}$ = 0V, $f$ =100kHz | | 0.11 | | nF |
| $L_{sDS}$ | 模块电感 Module inductance | | | 8 | | nH |
| $R_{DD'+SS'}$ | 模块引线电阻，端子-芯片 Module lead resistance, terminal-chip | | | 0.7 | | mΩ |
| $R_{Gint}$ | 内部栅极电阻 Internal gate resistor | | | 0.6 | | Ω |

## 电特性值 Electrical Characteristics

| 符号 Symbol | 参数名称 Parameter | 测试条件 Test Conditions | | 最小值 Min. | 典型值 Typ. | 最大值 Max. | 单位 Unit |
|---|---|---|---|---|---|---|---|
| $t_{d(off)}$ | 关断延迟时间 Turn-off delay time | $I_D$ =600A, $V_{DS}$ = 800V, $V_{GS}$ = -4/+18V, $R_{G(OFF)}$ = 5.1Ω, $L_S$ = 33nH, d$v$/d$t$ =10000V/μs ($T_{vj}$= 175 °C). | $T_{vj}$= 25 °C | | 450 | | ns |
| | | | $T_{vj}$= 150 °C | | 530 | | |
| | | | $T_{vj}$= 175 °C | | 550 | | |
| $t_f$ | 下降时间 Fall time | | $T_{vj}$= 25 °C | | 62 | | ns |
| | | | $T_{vj}$= 150 °C | | 64 | | |
| | | | $T_{vj}$= 175 °C | | 65 | | |
| $E_{OFF}$ | 关断损耗 Turn-off energy loss | | $T_{vj}$= 25 °C | | 67 | | mJ |
| | | | $T_{vj}$= 150 °C | | 69 | | |
| | | | $T_{vj}$= 175 °C | | 70 | | |
| $t_{d(on)}$ | 开通延迟时间 Turn-on delay time | $I_D$ =600A, $V_{DS}$ = 800V, $V_{GS}$ = -4/+18V, $R_{G(ON)}$ = 5.1Ω, $L_S$ = 33nH, d$i$/d$t$ = 14000A/μs ($T_{vj}$= 175 °C). | $T_{vj}$= 25 °C | | 75 | | ns |
| | | | $T_{vj}$= 150 °C | | 45 | | |
| | | | $T_{vj}$= 175 °C | | 45 | | |
| $t_r$ | 上升时间 Rise time | | $T_{vj}$= 25 °C | | 65 | | ns |
| | | | $T_{vj}$= 150 °C | | 56 | | |
| | | | $T_{vj}$= 175 °C | | 55 | | |
| $E_{ON}$ | 开通损耗 Turn-on energy loss | | $T_{vj}$= 25 °C | | 11.0 | | mJ |
| | | | $T_{vj}$= 150 °C | | 8.2 | | |
| | | | $T_{vj}$= 175 °C | | 8.1 | | |
| $Q_{rr}$ | 二极管反向恢复电荷 Diode reverse recovery charge | $I_D$ =600A, $V_{DS}$ = 800V, - d$i_F$/d$t$ = 14000A/μs ($T_{vj}$= 175 °C). | $T_{vj}$= 25 °C | | 4 | | μC |
| | | | $T_{vj}$= 150 °C | | 9 | | |
| | | | $T_{vj}$= 175 °C | | 11 | | |
| $I_{rr}$ | 二极管反向恢复电流 Diode reverse recovery current | | $T_{vj}$= 25 °C | | 170 | | A |
| | | | $T_{vj}$= 150 °C | | 285 | | |
| | | | $T_{vj}$= 175 °C | | 325 | | |
| $E_{rec}$ | 二极管反向恢复损耗 Diode reverse recovery energy | | $T_{vj}$= 25 °C | | 2.0 | | mJ |
| | | | $T_{vj}$= 150 °C | | 5.1 | | |
| | | | $T_{vj}$= 175 °C | | 6.3 | | |

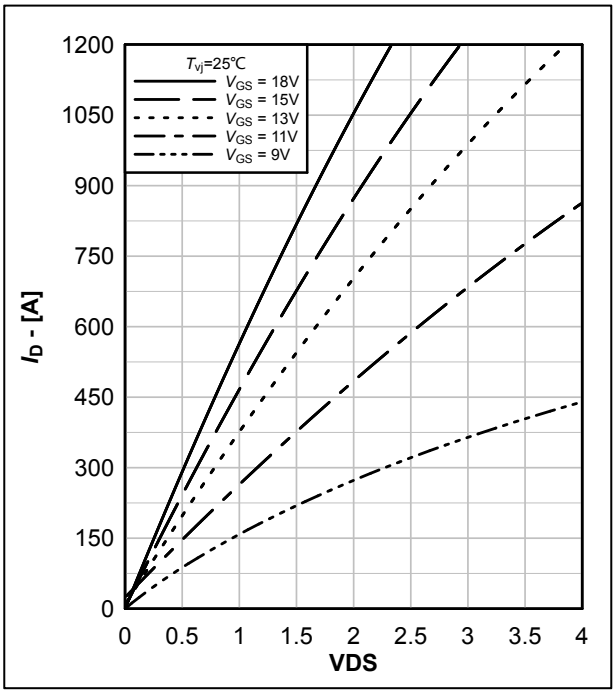



图 3. MOSFET 输出特性典型曲线, $I_D$= f ($V_{DS}$)

Fig.3 Typical MOSFET output characteristics, $I_D$= f ($V_{DS}$)

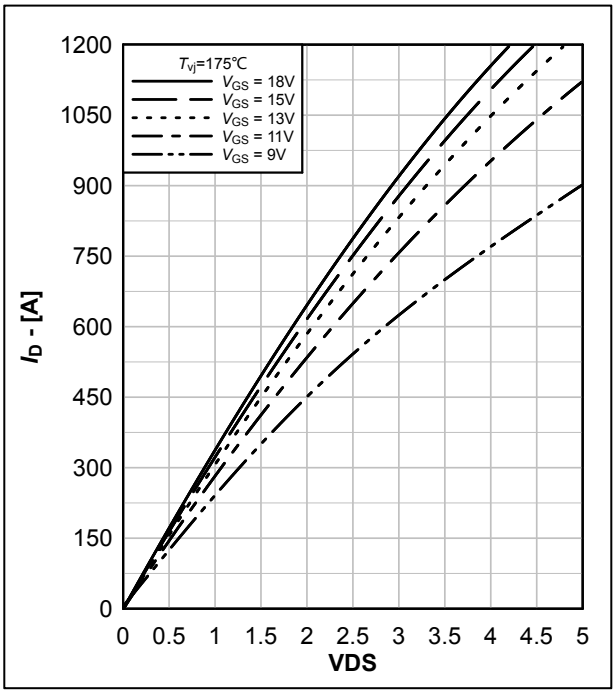



图 4. MOSFET 输出特性典型曲线, $I_D$= f ($V_{DS}$)

Fig.4 Typical MOSFET output characteristics, $I_D$= f ($V_{DS}$)

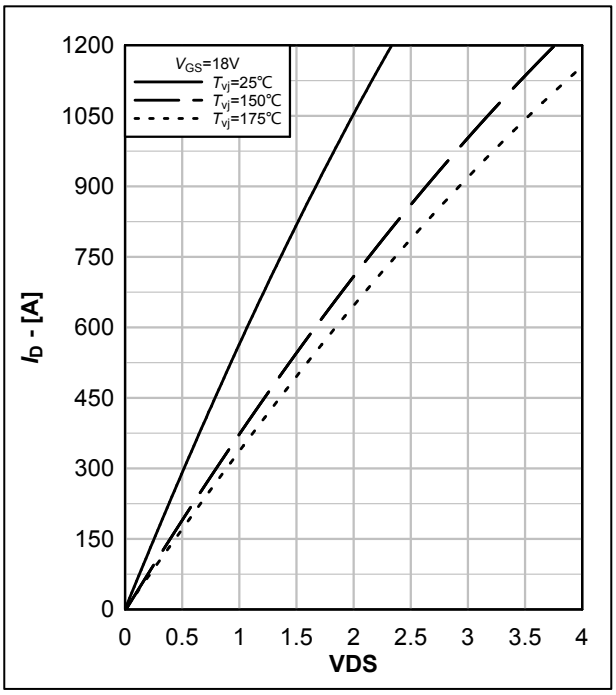



图 5. MOSFET 输出特性典型曲线, $I_D$= f ($V_{DS}$)

Fig.5 Typical MOSFET output characteristics, $I_D$= f ($V_{DS}$)

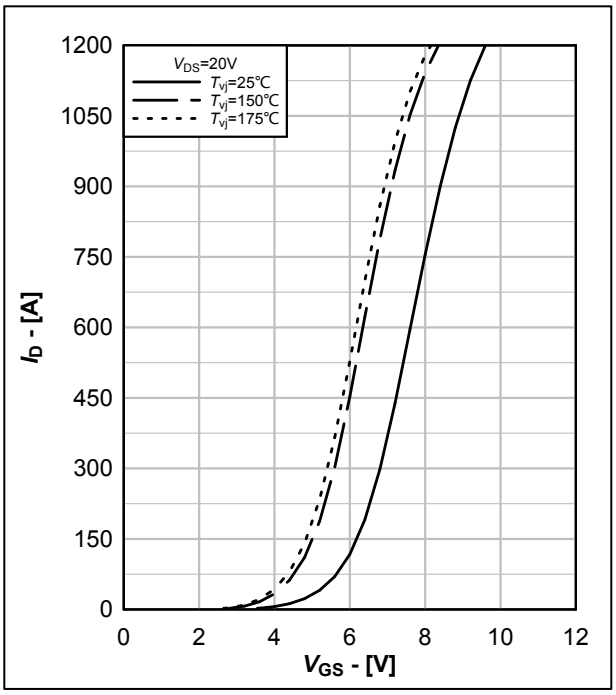



图 6. MOSFET 传输特性典型曲线,$I_D$= f ($V_{GS}$)

Fig.6 Typical MOSFET transfer characteristics, $I_D$= f ($V_{GS}$)

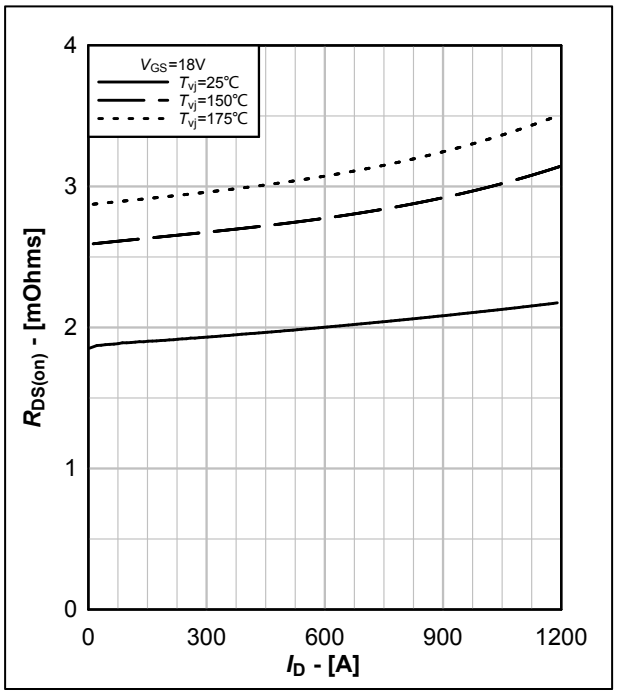



图 7. 导通电阻典型曲线, $R_{DS(on)}$ = f ($I_D$)

Fig.7 Typical On-Resistance characteristics, $R_{DS(on)}$ = f ($I_D$)

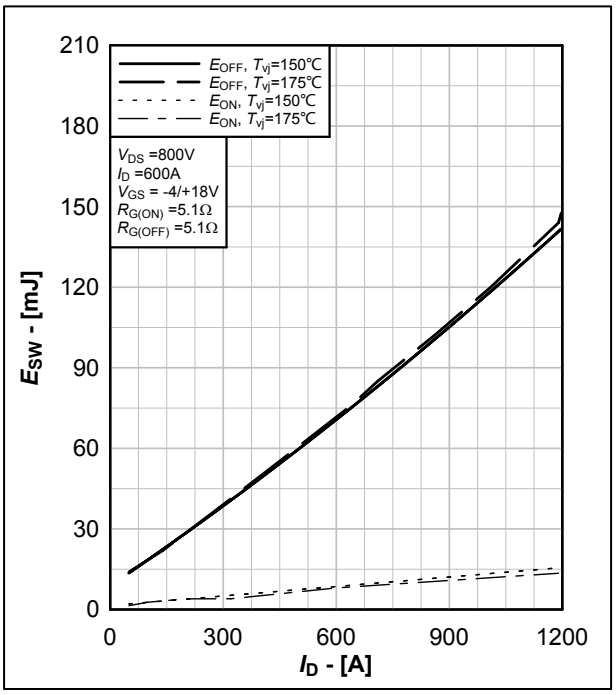



图 8. MOSFET 开关损耗典型曲线, $E_{on}$= f ($I_C$), $E_{off}$= f ($I_C$)

Fig.8 Typical MOSFET switching energy, $E_{on}$= f ($I_C$), $E_{off}$= f ($I_C$)

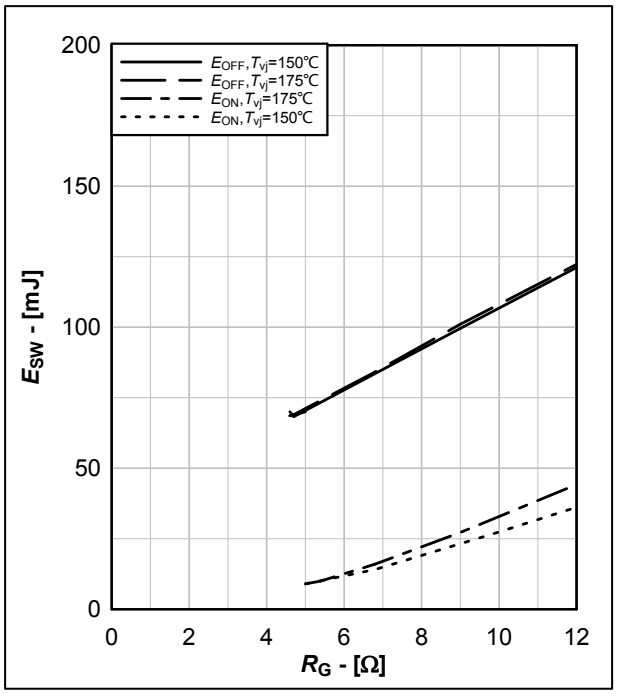



图 9. MOSFET 开关损耗典型曲线, $E_{on}$= f ($R_G$), $E_{off}$= f ($R_G$)

Fig.9 Typical MOSFET switching energy, $E_{on}$= f($R_G$), $E_{off}$= f ($R_G$)

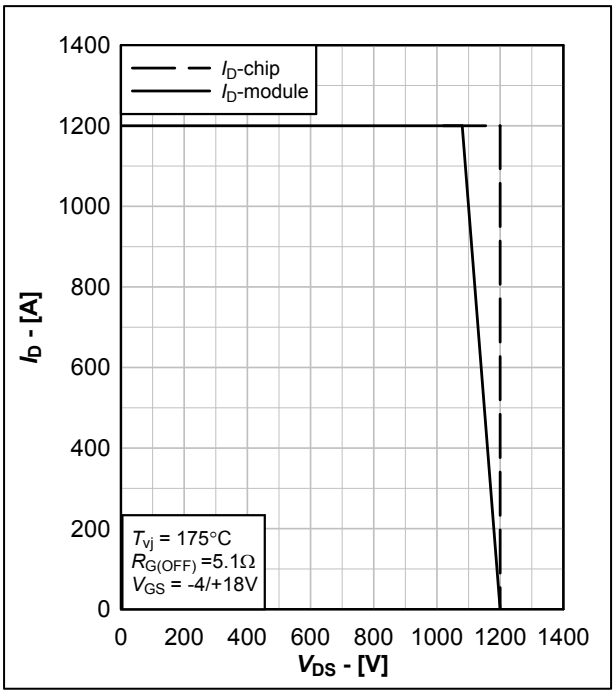



图 10. MOSFET 反偏安全工作区, $I_D$ = f ($V_{DS}$)

Fig.10 Reverse bias safe operating area of MOSFET, $I_D$ = f ($V_{DS}$)

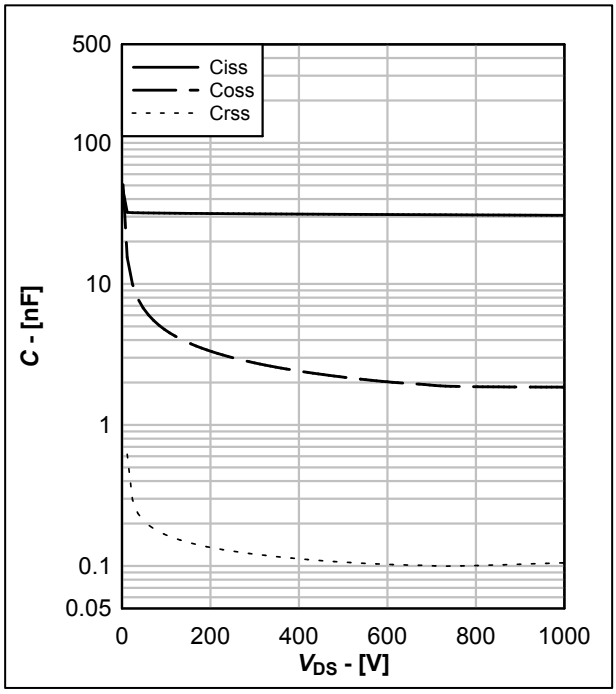



图 11. 电容特性典型曲线, $C$= f ($V_{DS}$)

Fig.11 Typical capacity characteristic, $C$= f ($V_{DS}$)

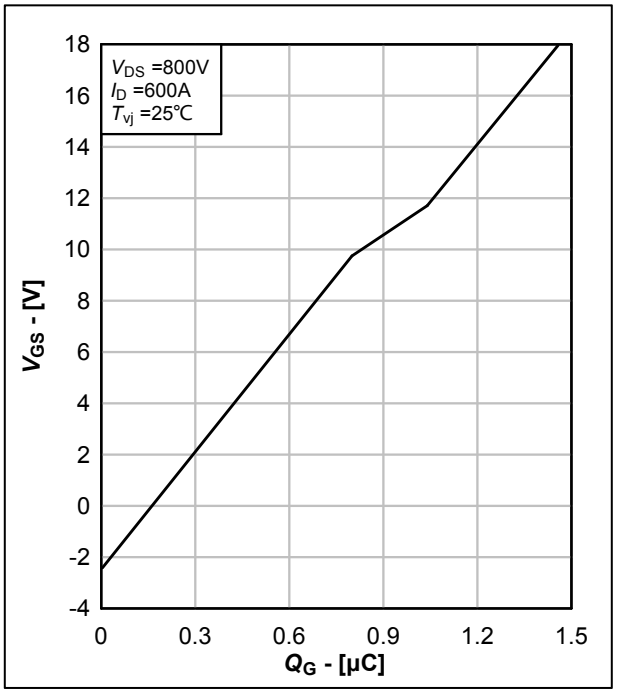



图 12. 栅极电荷特性典型曲线, $V_{GS}$ = f ($Q_G$)

Fig.12 Typical gate charge characteristic, $V_{GS}$= f ($Q_G$)

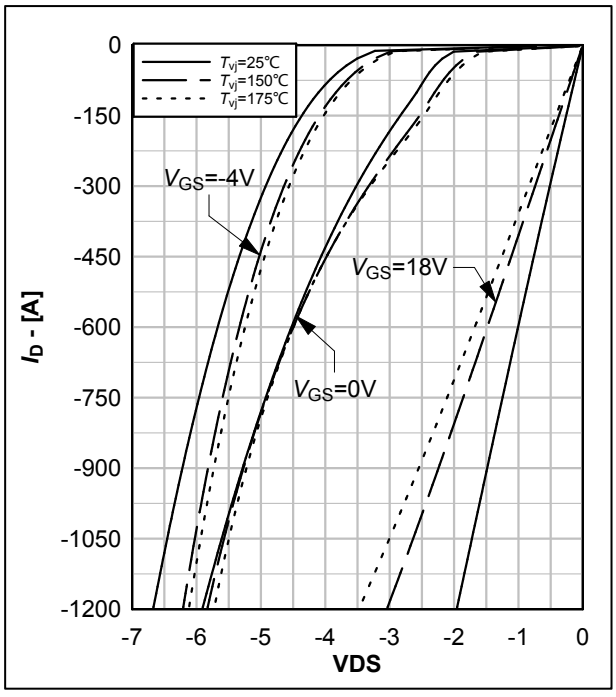



图 13. 体二极管及第三象限输出特性典型曲线, $I_D$ = f ($V_{DS}$)

Fig.13 Typical body diode output and 3rd quadrant characteristic, $I_D$ = f ($V_{DS}$)

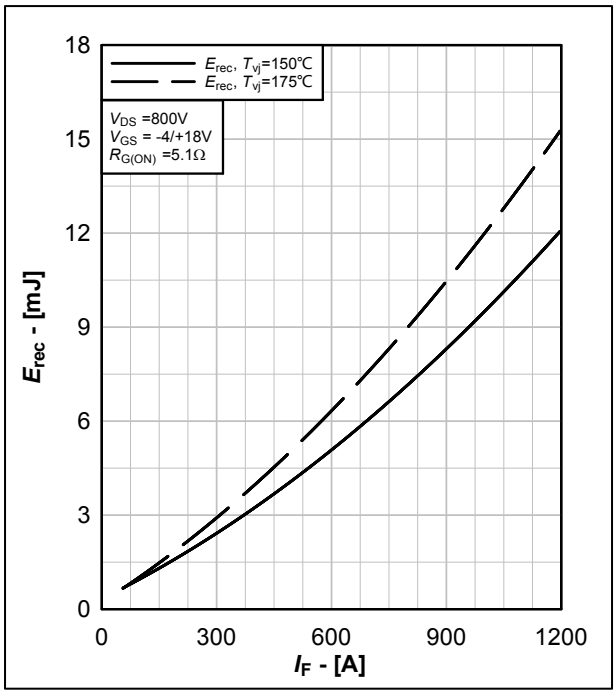



图 14. 体二极管反向恢复损耗典型曲线, $E_{rec}$=f($I_F$)

Fig.14 Typical body diode switching loss $E_{rec}$, $E_{rec}$=f($I_F$)

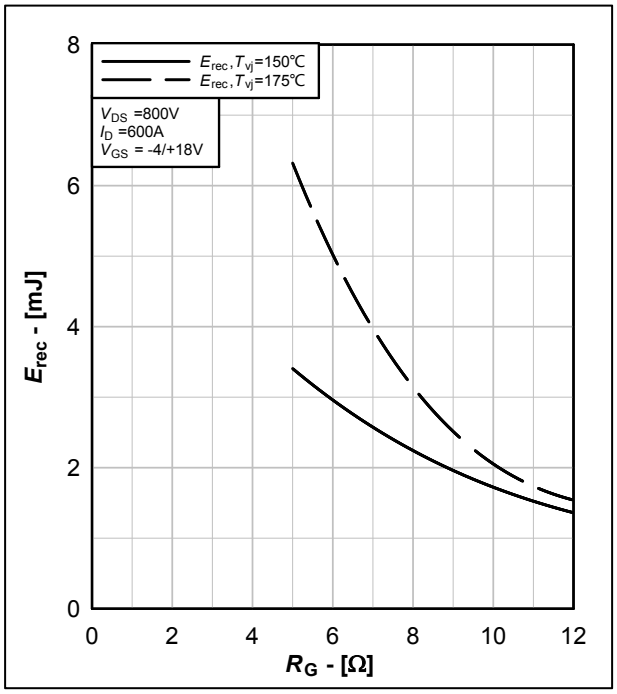



图 15. 体二极管反向恢复损耗典型曲线, $E_{rec}$=f($R_G$)

Fig.15 Typical body diode switching loss $E_{rec}$, $E_{rec}$=f($R_G$)

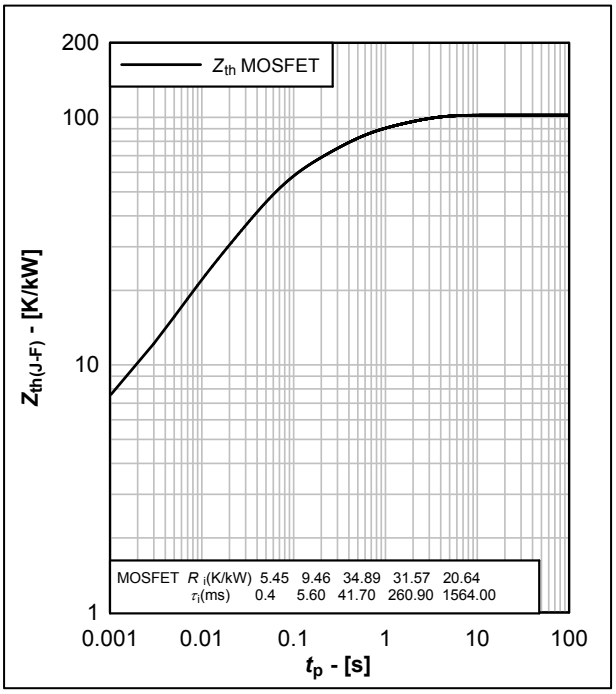



图 16. 瞬态热阻抗曲线, $Z_{th(J-F)}$ = f ($t_p$)

Fig.16 Transient thermal impedance, $Z_{th(J-F)}$ = f ($t_p$)

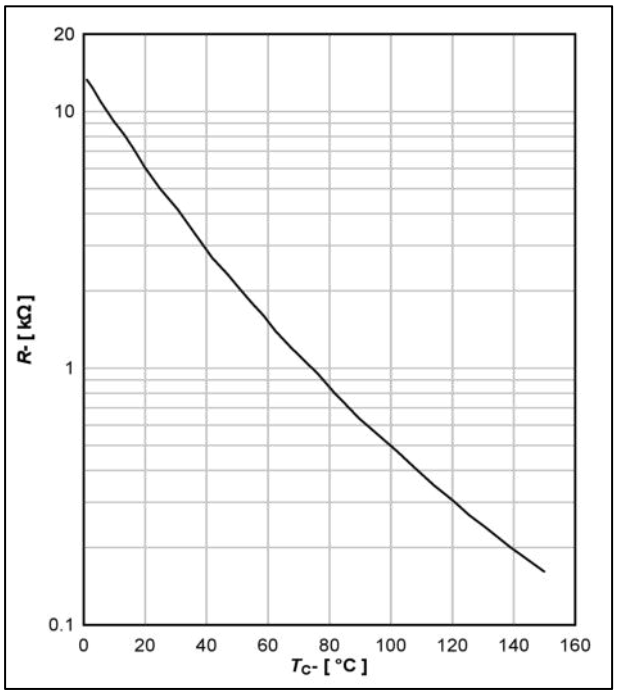
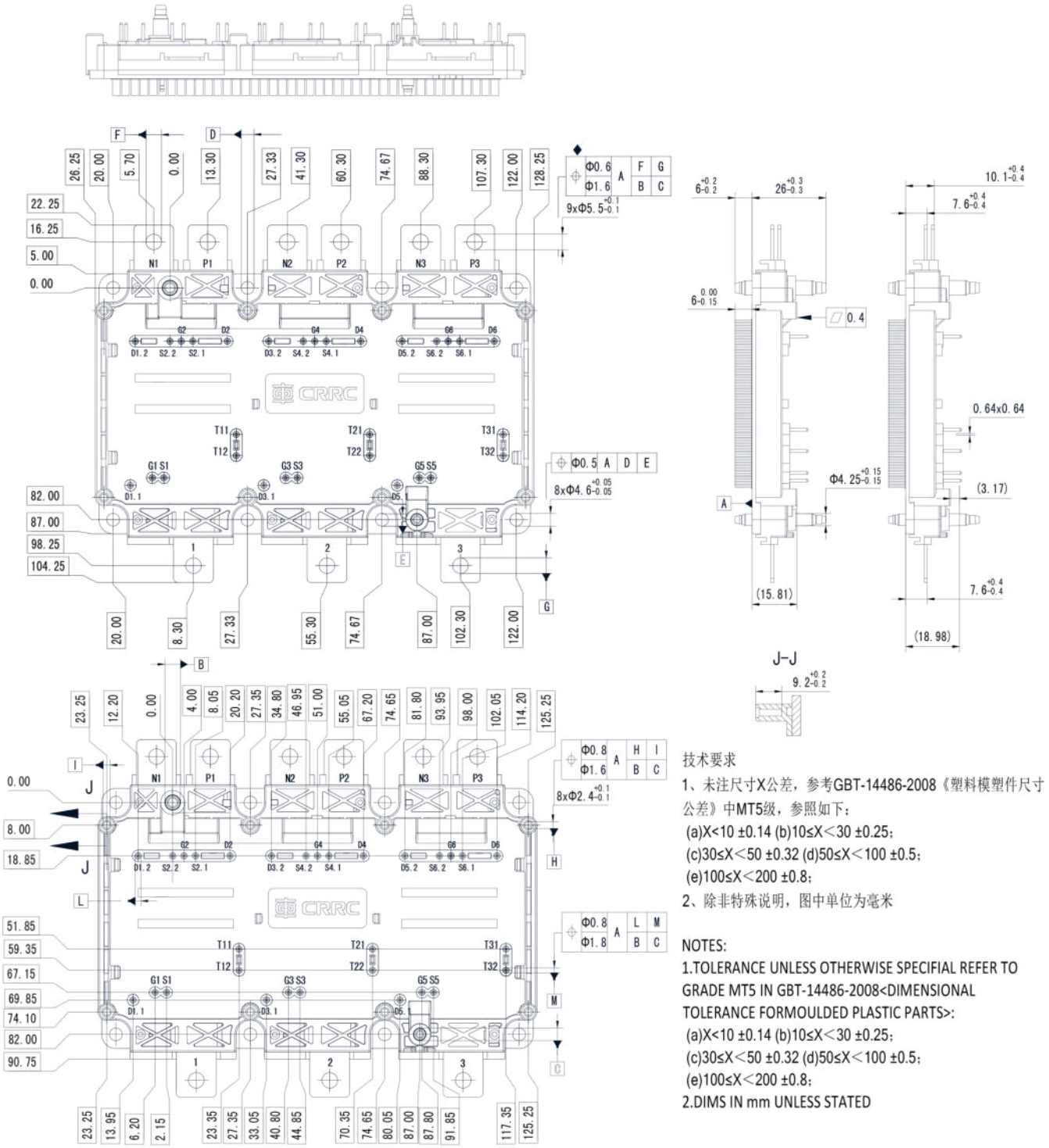



图 17. 热敏电阻典型特性曲线, $R$= f ($T_C$)

Fig.17 Typical NTC thermistor characteristic, $R$= f($T_C$)




重量 Weight：760g 模块外观类型 Module outline code：S3

图 18. 模块外观尺寸

Fig. 18 Module outlines

**株洲中车时代半导体有限公司**

**ZHUZHOU CRRC TIMES SEMICONDUCTOR CO., LTD.**

| | | | |
|---|---|---|---|
| 地　址 | Address | 湖南省株洲市石峰区田心工业园 | Tianxin Industrial Park, Shifeng District, ZhuZhou City, Hunan Province, China |
| 邮　编 | Zipcode | 412001 | |
| 电　话 | Telephone | +86 (0)731-28498268, 28498238, 28493472 | |
| 传　真 | Fax | +86 (0)731-28498851, 28498494 | |
| 电子邮箱 | Email | sbu@crrczic.cc | |
| 网　址 | Web Site | http://www.sbu.crrczic.cc | |

# 使用条件和条款

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(2) Some product data in the datasheet of this product are the typical values, the actual factory testing data may deviate slightly from typical values, but our company guarantees that these deviations will not affect the normal use of the product. If the product information changes, our company will promptly amend the datasheet, please keeps your attention to product information changing in our company website.

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(4) During the application, if the working conditions are beyond the limitation of temperature, voltage, current or safe operating area of the product defined in the product datasheet, our company cannot guarantee the reliability of the product.

(5) When the products are in use, it is strictly prohibited to touch. After power off, to ensure that there is no residual charge and the products have been cooled before they can be touched. And all operations must be under ESD protection measures.

(6) We annotate datasheet in the top right hand corner of the front page, to indicate product status. The annotation “Preliminary” indicates the product design is complete and final characterization for volume production is in progress， the product information in the datasheet is currently can be referenced, but some details may change in the future. There is no annotation indicates the product is capable to produce in batch quantity.