中国中车 CRRC

TH400AN10U4-S500

三电平 IGBT 模块 3-level IGBT Module

产品数据手册 Product Datasheet 版本 Ver 24.05

关键参数 Key Parameters

V_{CES}		950	V
$V_{CE(sat)}$	Typ.	1.28	V
I_C	Max.	400	A
$I_{C(RM)}$	Max.	800	A

典型应用 Typical Applications

- 三电平应用 3-level-applications Converters
- 光伏应用 Solar applications
- UPS 系统 UPS Systems

特点 Features

- SiC 二极管 Ultra-fast SiC Diode
- 低开关损耗 Low Switching Losses
- 低感设计 Low Inductive Design
- 集成 NTC Integrated NTC

电路结构 Circuit Configuration

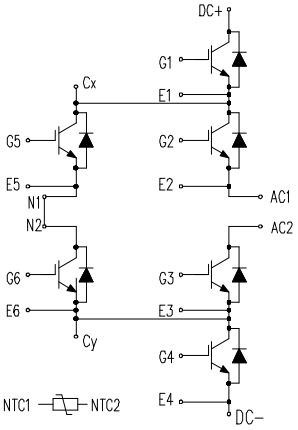


图 1. 电路结构

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
13--17	模块型号代码 Module type code
18--19	模块生产周数 Module production weeks

IGBT T1/T4，二极管 D1/D4　　IGBT T1/T4, Diode D1/D4

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_{CES}	集电极-发射极电压 Collector-emitter voltage	V_{GE} = 0V, T_C= 25 °C	950	V
V_{GES}	栅极-发射极电压 Gate-emitter voltage	T_C= 25 °C	± 20	V
I_C	集电极电流 Collector-emitter current	T_C = 90 °C, $T_{vj\ max}$=175°C	220	A
	额定电流 Rating Current		400	A
$I_{C(PK)}$	集电极峰值电流 Peak collector current	t_P=1ms	800	A
P_{max}	晶体管部分最大损耗 Max. transistor power dissipation	T_C = 25 °C, $T_{vj\ max}$=175°C	1	kW
I^2t	二极管 I^2t 值 Diode I^2t	V_R =0V, t_P = 10ms, T_{vj} = 150 °C	2.05	kA^2s

热数据　　Thermal 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
$R_{th(J-C)\ IGBT}$	IGBT 结壳热阻 Thermal resistance – IGBT				150	K / kW
$R_{th(J-C)\ Diode}$	二极管结壳热阻 Thermal resistance – Diode				324.5	K / kW
$R_{th(C-H)\ IGBT}$	接触热阻(IGBT) Thermal resistance – case to heatsink (IGBT)	安装力矩 3.5Nm，导热脂 3.3W/m·K Mounting torque 3.5Nm, with mounting grease 3.3W/m·K		90		K / kW
$R_{th(C-H)\ Diode}$	接触热阻(Diode) Thermal resistance – case to heatsink (Diode)	安装力矩 3.5Nm，导热脂 3.3W/m·K Mounting torque 3.5Nm, with mounting grease 3.3W/m·K		245.5		K / kW

IGBT T1/T4，二极管 D1/D4 IGBT T1/T4, Diode D1/D4

IGBT T1/T4，二极管 D1/D4　　IGBT T1/T4, Diode D1/D4

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_C =150A, V_{CE} = 500V, V_{GE} = -7.5/+15V, $R_{G(OFF)}$ = 20Ω, L_S = 25nH, dv/dt =5500V/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		665		ns
			T_{vj}= 125 °C		725		
			T_{vj}= 150 °C		745		
t_f	下降时间 Fall time		T_{vj}= 25 °C		75		ns
			T_{vj}= 125 °C		95		
			T_{vj}= 150 °C		105		
E_{OFF}	关断损耗 Turn-off energy loss		T_{vj}= 25 °C		6.4		mJ
			T_{vj}= 125 °C		7.7		
			T_{vj}= 150 °C		8.3		
$t_{d(on)}$	开通延迟时间 Turn-on delay time	I_C =150A, V_{CE} = 500V, V_{GE} = -7.5/+15V, $R_{G(ON)}$ = 5Ω, L_S = 25nH, di/dt = 3700A/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		165		ns
			T_{vj}= 125 °C		160		
			T_{vj}= 150 °C		160		
t_r	上升时间 Rise time		T_{vj}= 25 °C		34		ns
			T_{vj}= 125 °C		38		
			T_{vj}= 150 °C		39		
E_{ON}	开通损耗 Turn-on energy loss		T_{vj}= 25 °C		3.4		mJ
			T_{vj}= 125 °C		3.6		
			T_{vj}= 150 °C		3.8		
Q_{rr}	二极管反向恢复电荷 Diode reverse recovery charge	I_F =150A, V_{CE} = 500V, $R_{G(ON)}$ = 5Ω, - di_F/dt = 3200A/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		6		μC
			T_{vj}= 125 °C		11		
			T_{vj}= 150 °C		12		
I_{rr}	二极管反向恢复电流 Diode reverse recovery current		T_{vj}= 25 °C		65		A
			T_{vj}= 125 °C		84		
			T_{vj}= 150 °C		85		
E_{rec}	二极管反向恢复损耗 Diode reverse recovery energy		T_{vj}= 25 °C		1.6		mJ
			T_{vj}= 125 °C		3.7		
			T_{vj}= 150 °C		3.9		

IGBT T2/T3，二极管 D2/D3　　IGBT T2/T3, Diode D2/D3

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_{CES}	集电极-发射极电压 Collector-emitter voltage	V_{GE} = 0V, T_C= 25 °C	950	V
V_{GES}	栅极-发射极电压 Gate-emitter voltage	T_C= 25 °C	± 20	V
I_C	集电极电流 Collector-emitter current	T_C = 90 °C, $T_{vj\ max}$=175°C	295	A
	额定电流 Rating Current		400	A
$I_{C(PK)}$	集电极峰值电流 Peak collector current	t_P=1ms	800	A
P_{max}	晶体管部分最大损耗 Max. transistor power dissipation	T_C = 25 °C, $T_{vj\ max}$=175°C	1	kW
I^2t	二极管 I^2t 值 Diode I^2t	V_R =0V, t_P = 10ms, T_{vj} = 150 °C	2.05	kA^2s

热数据　　Thermal 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
$R_{th(J-C)\ IGBT}$	IGBT 结壳热阻 Thermal resistance – IGBT				150	K / kW
$R_{th(J-C)\ Diode}$	二极管结壳热阻 Thermal resistance – Diode				364	K / kW
$R_{th(C-H)\ IGBT}$	接触热阻(IGBT) Thermal resistance – case to heatsink (IGBT)	安装力矩 3.5Nm，导热脂 3.3W/m·K Mounting torque 3.5Nm, with mounting grease 3.3W/m·K		90		K / kW
$R_{th(C-H)\ Diode}$	接触热阻(Diode) Thermal resistance – case to heatsink (Diode)	安装力矩 3.5Nm，导热脂 3.3W/m·K Mounting torque 3.5Nm, with mounting grease 3.3W/m·K		206		K / kW

IGBT T2/T3，二极管 D2/D3　　IGBT T2/T3, Diode D2/D3

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_{CES}	集电极截止电流 Collector cut-off current	V_{GE} = 0V,V_{CE} = V_{CES}			1	mA
		V_{GE} = 0V, V_{CE} = V_{CES}, T_{vj}=125 °C			5	mA
		V_{GE} = 0V, V_{CE} = V_{CES}, T_{vj}=150 °C			10	mA
I_{GES}	栅极漏电流 Gate leakage current	V_{GE} = ±20V, V_{CE} = 0V			0.5	μA
$V_{GE\ (th)}$	栅极-发射极阈值电压 Gate threshold voltage	I_C = 10mA, V_{GE} = V_{CE}	4.70	5.30	5.90	V
$V_{CE\ (sat)}$ (*1)	集电极-发射极饱和电压 Collector-emitter saturation voltage	V_{GE} =15V, I_C = 150A		1.05	1.35	V
		V_{GE} =15V, I_C = 150A,T_{vj} = 125 °C		1.05		V
		V_{GE} =15V, I_C = 150A,T_{vj} = 150 °C		1.05		V
I_F	二极管正向直流电流 Diode forward current	DC		150		A
	二极管额定正向电流 Diode ratingforward current			200		A
I_{FRM}	二极管正向重复峰值电流 Diode peak forward current	t_P = 1ms		400		A
V_F (*1)	二极管正向电压 Diode forward voltage	I_F = 150A, V_{GE} = 0V		2.05	2.45	V
		I_F = 150A, V_{GE} = 0V, T_{vj} = 125 °C		2.25		V
		I_F = 150A, V_{GE} = 0V, T_{vj} = 150 °C		2.20		V
C_{ies}	输入电容 Input capacitance	V_{CE} = 25V, V_{GE} = 0V, f = 100kHz		41		nF
Q_g	栅极电荷 Gate charge	-7.5/+15V		2.2		μC
C_{res}	反向传输电容 Reverse transfer capacitance	V_{CE} = 25V, V_{GE} = 0V, f = 100kHz		0.14		nF
R_{Gint}	内部栅极电阻 Internal gate resistor			3		Ω

注意： 1.(*1) 表示该参数基于芯片水平给出((*1) indicates it is given at chip level),

Note: 2.(*2) 表示 L 是电路杂散电感加上 L_{sCE} ((*2) indicates L is the circuit stray inductance plus L_{sCE}).

IGBT T2/T3，二极管 D2/D3　　IGBT T2/T3, Diode D2/D3

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_C =150A, V_{CE} = 500V, V_{GE} = -7.5/+15V, $R_{G(OFF)}$ = 5Ω, L_S = 55nH, dv/dt =2200V/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		765		ns
			T_{vj}= 125 °C		850		
			T_{vj}= 150 °C		870		
t_f	下降时间 Fall time		T_{vj}= 25 °C		160		ns
			T_{vj}= 125 °C		235		
			T_{vj}= 150 °C		265		
E_{OFF}	关断损耗 Turn-off energy loss		T_{vj}= 25 °C		15		mJ
			T_{vj}= 125 °C		20		
			T_{vj}= 150 °C		21		
$t_{d(on)}$	开通延迟时间 Turn-on delay time	I_C =150A, V_{CE} = 500V, V_{GE} = -7.5/+15V, $R_{G(ON)}$ = 5Ω, L_S = 55nH, di/dt = 5200A/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		290		ns
			T_{vj}= 125 °C		285		
			T_{vj}= 150 °C		280		
t_r	上升时间 Rise time		T_{vj}= 25 °C		34		ns
			T_{vj}= 125 °C		35		
			T_{vj}= 150 °C		38		
E_{ON}	开通损耗 Turn-on energy loss		T_{vj}= 25 °C		1.5		mJ
			T_{vj}= 125 °C		2.8		
			T_{vj}= 150 °C		3.3		
Q_{rr}	二极管反向恢复电荷 Diode reverse recovery charge	I_F =150A, V_{CE} = 500V, $R_{G(ON)}$ = 5Ω, - di_F/dt = 5200A/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		6		μC
			T_{vj}= 125 °C		12		
			T_{vj}= 150 °C		13		
I_{rr}	二极管反向恢复电流 Diode reverse recovery current		T_{vj}= 25 °C		140		A
			T_{vj}= 125 °C		145		
			T_{vj}= 150 °C		150		
E_{rec}	二极管反向恢复损耗 Diode reverse recovery energy		T_{vj}= 25 °C		2.5		mJ
			T_{vj}= 125 °C		4.6		
			T_{vj}= 150 °C		4.9		

IGBT T5/T6，二极管 D5/D6　　IGBT T5/T6, Diode D5/D6

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_{CES}	集电极-发射极电压 Collector-emitter voltage	V_{GE} = 0V, T_C= 25 °C	950	V
V_{GES}	栅极-发射极电压 Gate-emitter voltage	T_C= 25 °C	± 20	V
I_C	集电极电流 Collector-emitter current	T_C = 90 °C, $T_{vj\ max}$=175°C	115	A
	额定电流 Rating Current		200	A
$I_{C(PK)}$	集电极峰值电流 Peak collector current	t_P=1ms	400	A
P_{max}	晶体管部分最大损耗 Max. transistor power dissipation	T_C = 25 °C, $T_{vj\ max}$=175°C	0.53	kW
I^2t	二极管 I^2t 值 Diode I^2t	V_R =0V, t_P = 10ms, T_{vj} = 150 °C	2.3	kA^2s

热数据　　Thermal 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
$R_{th(J-C)\ IGBT}$	IGBT 结壳热阻 Thermal resistance – IGBT				284.7	K / kW
$R_{th(J-C)\ Diode}$	二极管结壳热阻 Thermal resistance – Diode				295.8	K / kW
$R_{th(C-H)\ IGBT}$	接触热阻(IGBT) Thermal resistance – case to heatsink (IGBT)	安装力矩 3.5Nm，导热脂 3.3W/m·K Mounting torque 3.5Nm, with mounting grease 3.3W/m·K		166.3		K / kW
$R_{th(C-H)\ Diode}$	接触热阻(Diode) Thermal resistance – case to heatsink (Diode)	安装力矩 3.5Nm，导热脂 3.3W/m·K Mounting torque 3.5Nm, with mounting grease 3.3W/m·K		178.2		K / kW

IGBT T5/T6，二极管 D5/D6　　IGBT T5/T6, Diode D5/D6

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_{CES}	集电极截止电流 Collector cut-off current	V_{GE} = 0V,V_{CE} = V_{CES}			1	mA
		V_{GE} = 0V, V_{CE} = V_{CES}, T_{vj} =125 °C			3	mA
		V_{GE} = 0V, V_{CE} = V_{CES}, T_{vj} =150 °C			5	mA
I_{GES}	栅极漏电流 Gate leakage current	V_{GE} = ±20V, V_{CE} = 0V			0.5	μA
$V_{GE\ (th)}$	栅极-发射极阈值电压 Gate threshold voltage	I_C = 5mA, V_{GE} = V_{CE}	5.00	5.60	6.20	V
$V_{CE\ (sat)}$(*1)	集电极-发射极饱和电压 Collector-emitter saturation voltage	V_{GE} =15V, I_C = 150A		1.60	2.00	V
		V_{GE} =15V, I_C = 150A,T_{vj} = 125 °C		1.95		V
		V_{GE} =15V, I_C = 150A,T_{vj} = 150 °C		2.05		V
I_F	二极管正向直流电流 Diode forward current	DC		100		A
I_{FRM}	二极管正向重复峰值电流 Diode peak forward current	t_P = 1ms		200		A
V_F(*1)	二极管正向电压 Diode forward voltage	I_F = 150A, V_{GE} = 0V		1.50	1.80	V
		I_F = 150A, V_{GE} = 0V, T_{vj} = 125 °C		1.90		V
		I_F = 150A, V_{GE} = 0V, T_{vj} = 150 °C		2.00		V
C_{ies}	输入电容 Input capacitance	V_{CE} = 25V, V_{GE} = 0V, f = 100kHz		12		nF
Q_g	栅极电荷 Gate charge	-7.5/+15V		0.6		μC
C_{res}	反向传输电容 Reverse transfer capacitance	V_{CE} = 25V, V_{GE} = 0V, f = 100kHz		0.04		nF
R_{Gint}	内部栅极电阻 Internal gate resistor			2.2		Ω

注意： 1.(*1) 表示该参数基于芯片水平给出((*1) indicates it is given at chip level),

Note: 2.(*2) 表示 L 是电路杂散电感加上 L_{sCE} ((*2) indicates L is the circuit stray inductance plus L_{sCE}).

IGBT T5/T6，二极管 D5/D6　　IGBT T5/T6, Diode D5/D6

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_C =150A, V_{CE} = 500V, V_{GE} = -7.5/+15V, $R_{G(OFF)}$ = 33Ω, L_S = 25nH, dv/dt =7200V/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		554		ns
			T_{vj}= 125 °C		580		
			T_{vj}= 150 °C		590		
t_f	下降时间 Fall time		T_{vj}= 25 °C		70		ns
			T_{vj}= 125 °C		85		
			T_{vj}= 150 °C		100		
E_{OFF}	关断损耗 Turn-off energy loss		T_{vj}= 25 °C		6.5		mJ
			T_{vj}= 125 °C		7.7		
			T_{vj}= 150 °C		8.6		
$t_{d(on)}$	开通延迟时间 Turn-on delay time	I_C =150A, V_{CE} = 500V, V_{GE} = -7.5/+15V, $R_{G(ON)}$ = 5Ω, L_S = 25nH, di/dt = 3200A/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		100		ns
			T_{vj}= 125 °C		95		
			T_{vj}= 150 °C		95		
t_r	上升时间 Rise time		T_{vj}= 25 °C		30		ns
			T_{vj}= 125 °C		35		
			T_{vj}= 150 °C		40		
E_{ON}	开通损耗 Turn-on energy loss		T_{vj}= 25 °C		6.0		mJ
			T_{vj}= 125 °C		7.6		
			T_{vj}= 150 °C		8.3		
Q_{rr}	二极管反向恢复电荷 Diode reverse recovery charge	I_F =100A, V_{CE} = 500V, $R_{G(ON)}$ = 5Ω, - di_F/dt = 3700A/μs (T_{vj}= 150 °C).	T_{vj}= 25 °C		0.5		μC
			T_{vj}= 125 °C		1.0		
			T_{vj}= 150 °C		1.2		
I_{rr}	二极管反向恢复电流 Diode reverse recovery current		T_{vj}= 25 °C		30		A
			T_{vj}= 125 °C		31		
			T_{vj}= 150 °C		32		
E_{rec}	二极管反向恢复损耗 Diode reverse recovery energy		T_{vj}= 25 °C		0.10		mJ
			T_{vj}= 125 °C		0.11		
			T_{vj}= 150 °C		0.12		

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	R100 偏差 Deviation of R100	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

模块 Module

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	11.5	mm
	端子-端子 Terminal to terminal	6.8	mm
绝缘间隙 Clearance	端子-散热器 Terminal to heatsink	9.4	mm
	端子-端子 Terminal to terminal	5.5	mm
相对漏电起痕指数 CTI (Comparative Tracking Index)		>400	
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 base plate), AC RMS,1 min, 50Hz, T_C= 25 °C	3200	V

模块 Module

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
L_{sCE}	模块电感 Module inductance			15		nH
$T_{vj\ op}$	工作结温 Operating junction temperature	IGBT 芯片(IGBT)	-40		150	°C
		二极管芯片(Diode)	-40		150	°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 Mounting	3		5	Nm

IGBT T1/T4，二极管 D1/D4　　IGBT T1/T4, Diode D1/D4

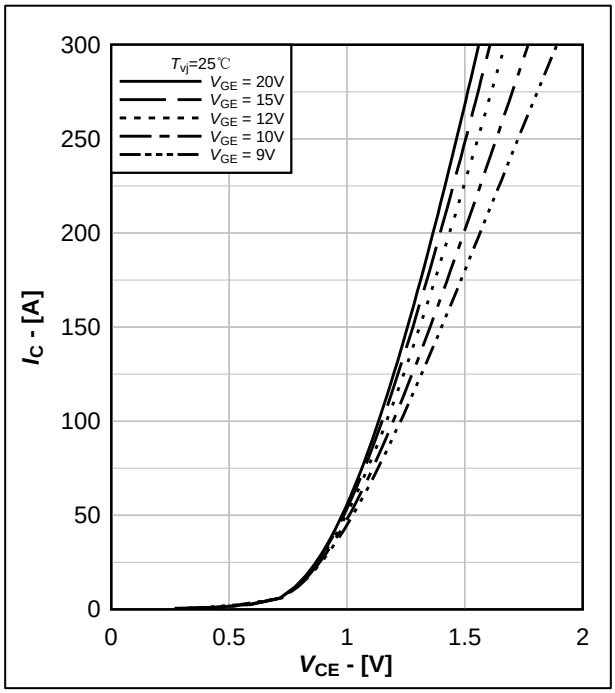


图 3. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.3 Typical IGBT output characteristic, I_C= f (V_{CE})

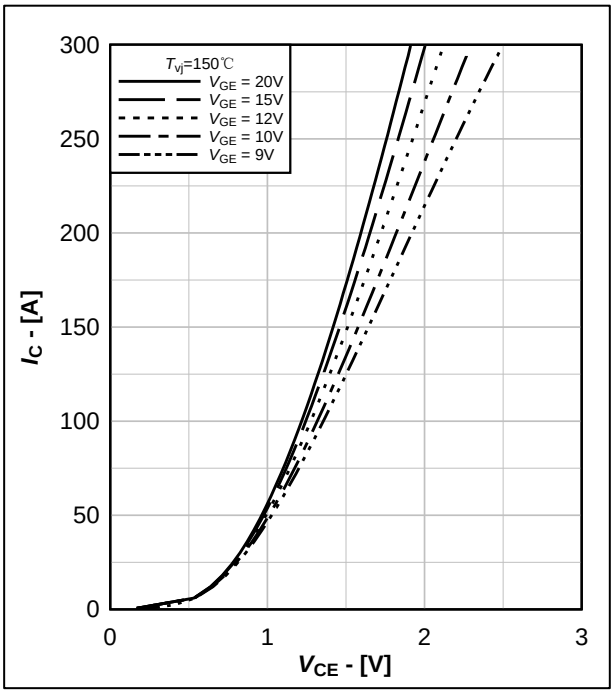


图 4. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.4 Typical IGBT output characteristic, I_C= f (V_{CE})

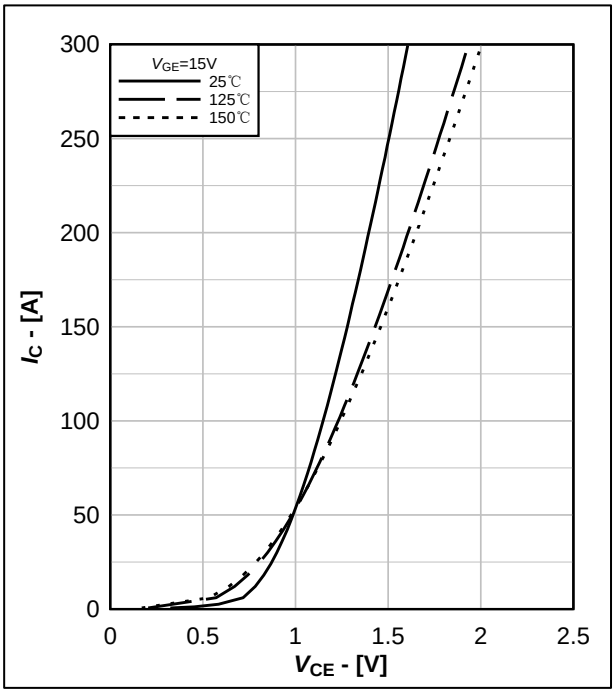


图 5. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.5 Typical IGBT output characteristic, I_C= f (V_{CE})

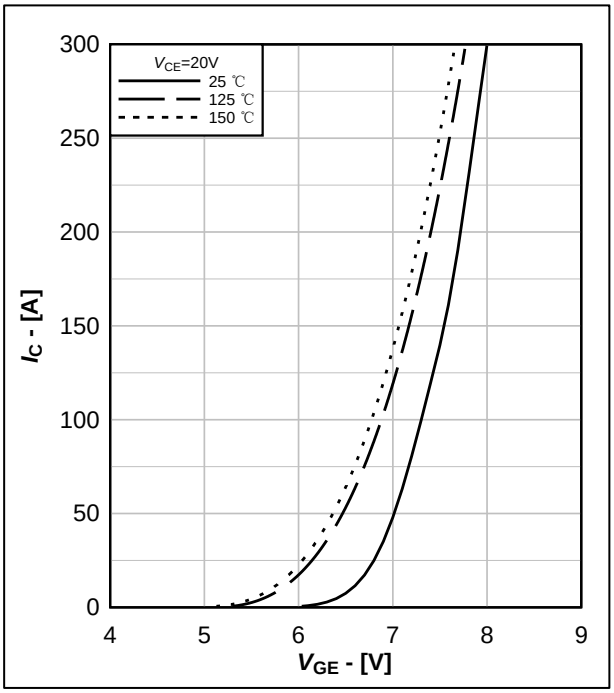


图 6. IGBT 传输特性典型曲线, I_C= f (V_{GE})

Fig.6 Typical IGBT transfer characteristic, I_C= f (V_{GE})

IGBT T1/T4，二极管 D1/D4

IGBT T1/T4, Diode D1/D4

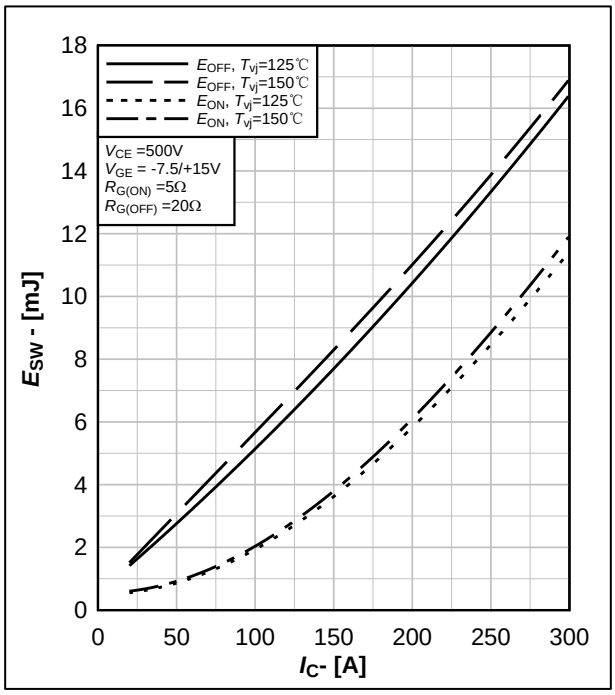


图 7. IGBT 开关损耗典型曲线, E_{on}= f (I_C), E_{off}= f (I_C)

Fig.7 Typical IGBT switching energy, E_{on}= f (I_C), E_{off}= f (I_C)

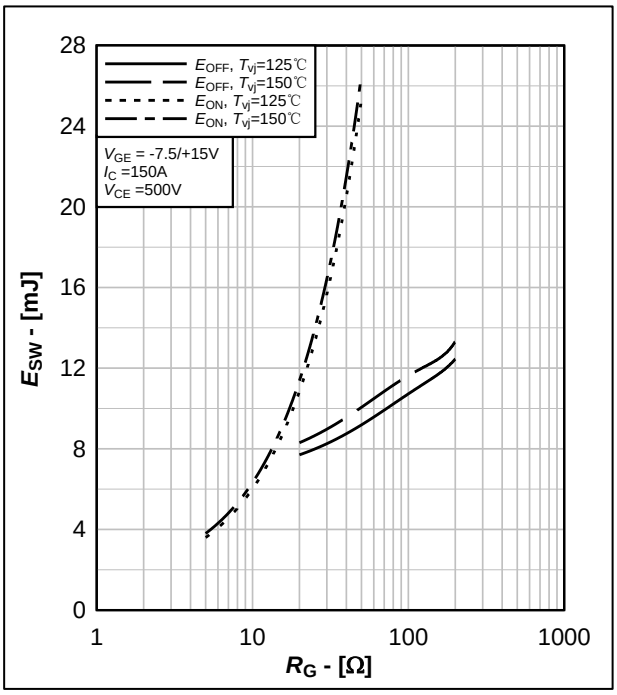


图 8. IGBT 开关损耗典型曲线, E_{on}= f (R_G), E_{off}= f (R_G)

Fig.8 Typical IGBT switching energy, E_{on}= f(R_G), E_{off}= f (R_G)

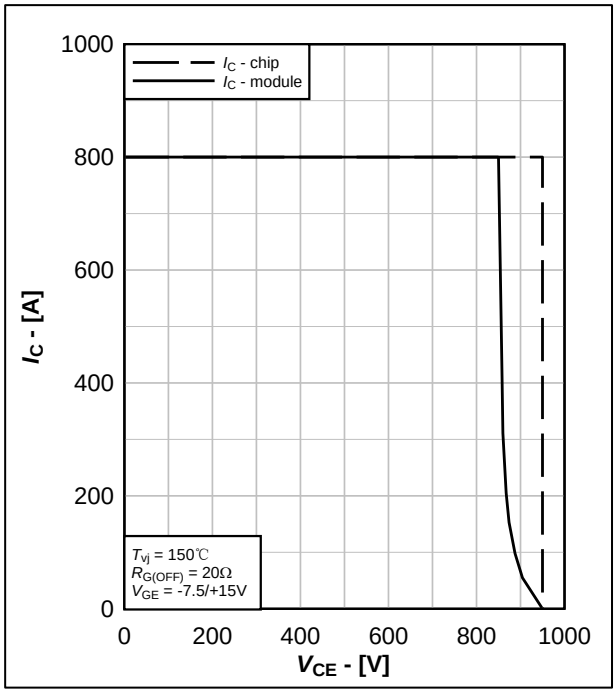


图 9. IGBT 反偏安全工作区, I_C = f (V_{CE})

Fig.9 Reverse bias safe operating area of IGBT, I_C = f (V_{CE})

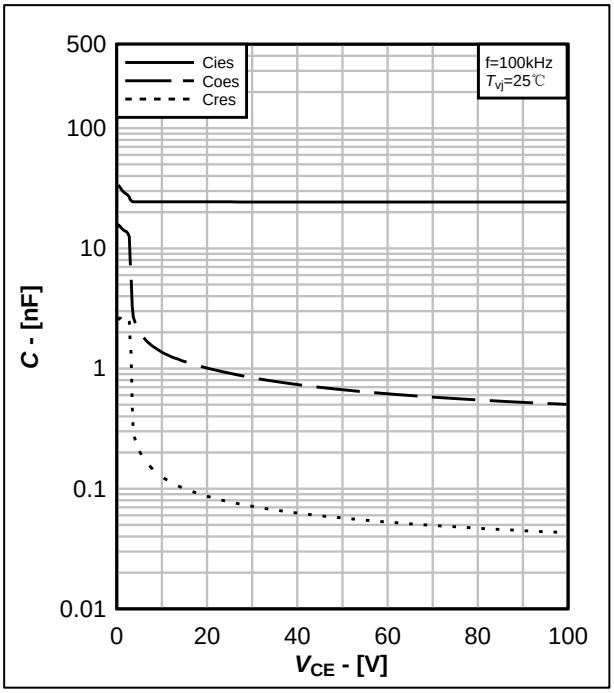


图 10. 电容特性典型曲线, C= f (V_{CE})

Fig.10 Typical capacity characteristic, C= f (V_{CE})

IGBT T1/T4，二极管 D1/D4

IGBT T1/T4, Diode D1/D4

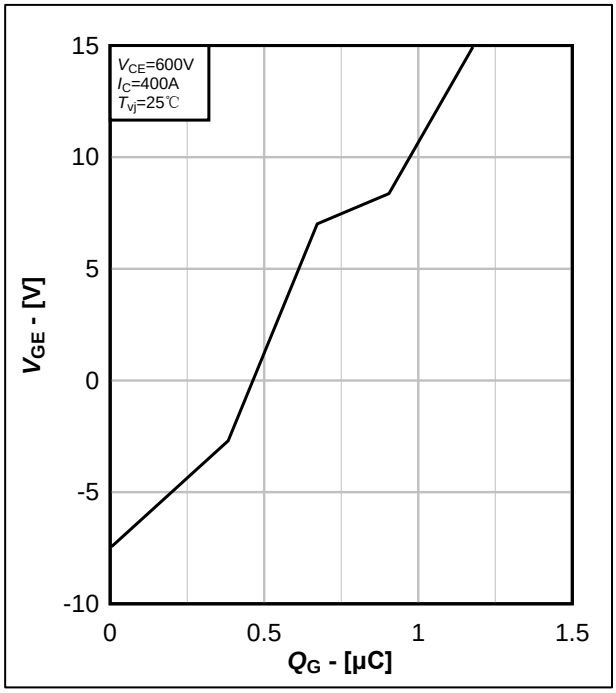


图 11. 栅极电荷特性典型曲线, V_{GE} = f (Q_G)

Fig.11 Typical gate charge characteristic, V_{GE}= f (Q_G)

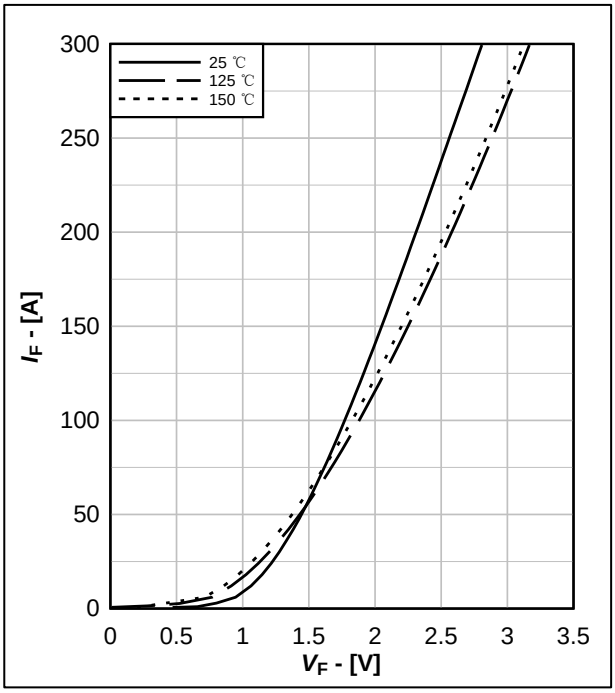


图 12. FRD 输出特性典型曲线, I_F = f (V_F)

Fig.12 Typical FRD output characteristic, I_F = f (V_F)

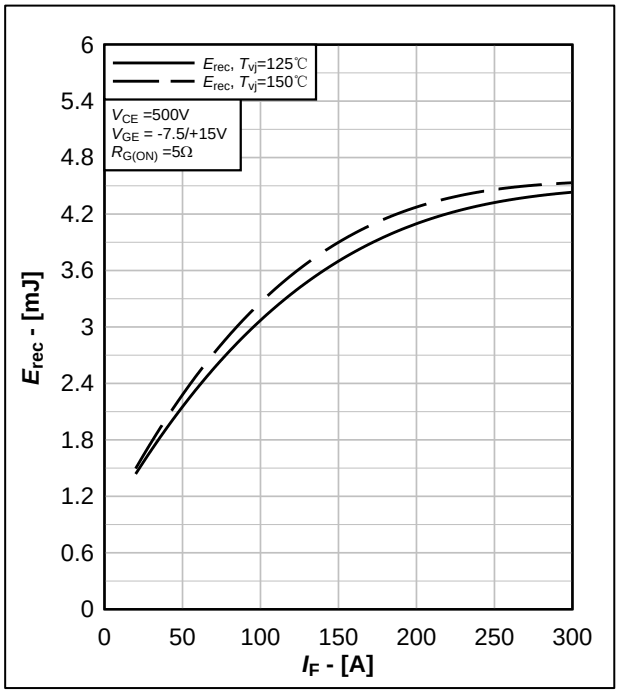


图 13. FRD 反向恢复损耗典型曲线, E_{rec}=f(I_F)

Fig.13 Typical FRD switching loss E_{rec}, E_{rec}=f(I_F)

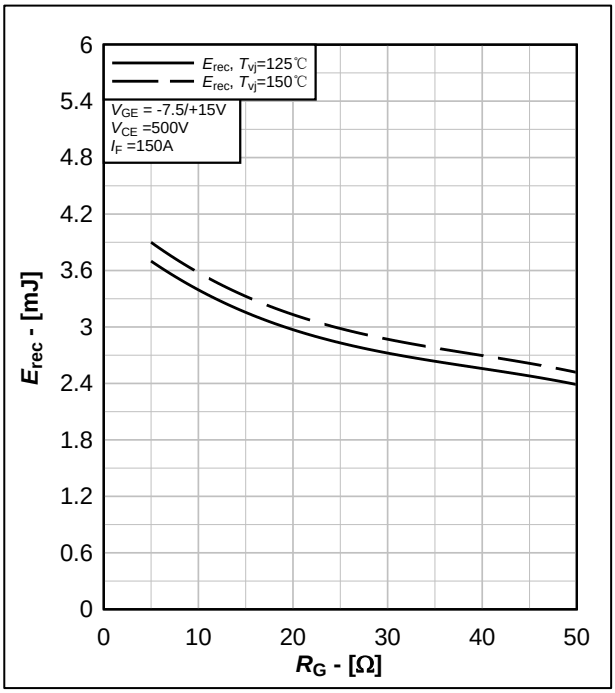


图 14. FRD 反向恢复损耗典型曲线, E_{rec}=f(R_G)

Fig.14 Typical FRD switching loss E_{rec}, E_{rec}=f(R_G)

IGBT T1/T4，二极管 D1/D4

IGBT T1/T4, Diode D1/D4

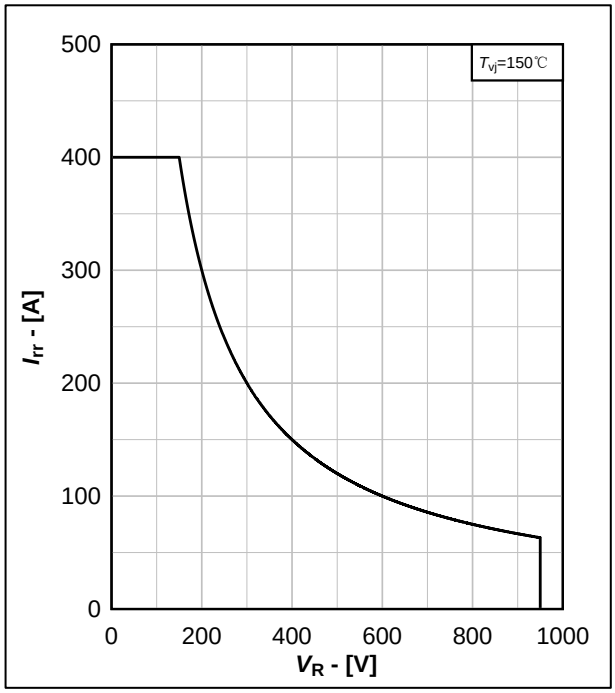


图 15. FRD 反偏安全工作区, I_{rr} = f (V_R)

Fig.15 Reverse bias safe operating area of FRD, I_{rr} = f (V_R)

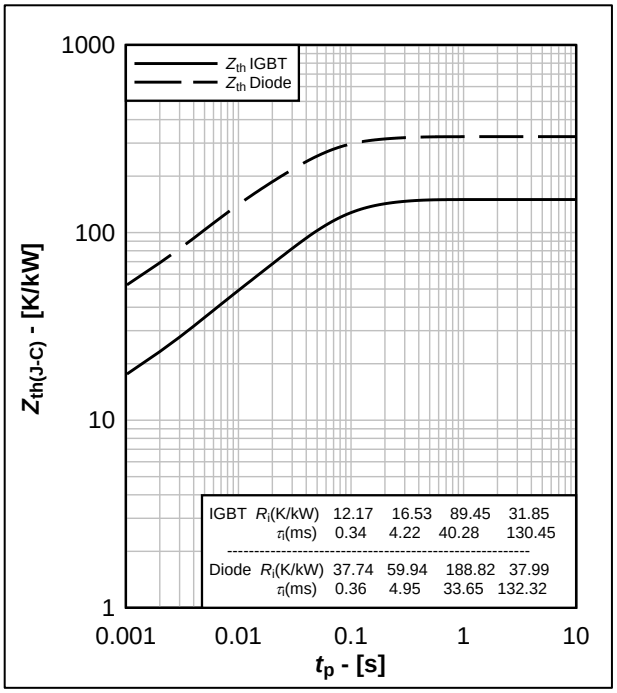


图 16. 瞬态热阻抗曲线, $Z_{th(J-C)}$ = f (t_p)

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

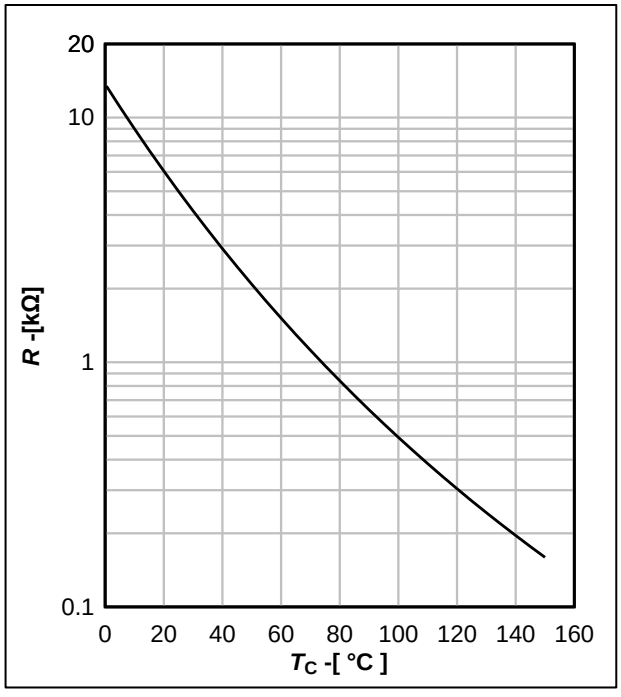


图 17. 热敏电阻典型特性曲线, R= f (T_C)

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

IGBT T2/T3，二极管 D2/D3

IGBT T2/T3, Diode D2/D3

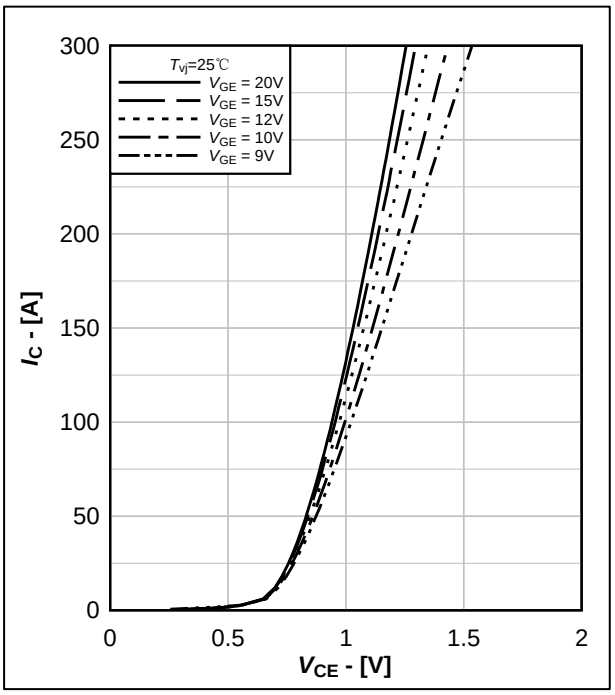


图 18. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.18 Typical IGBT output characteristic, I_C= f (V_{CE})

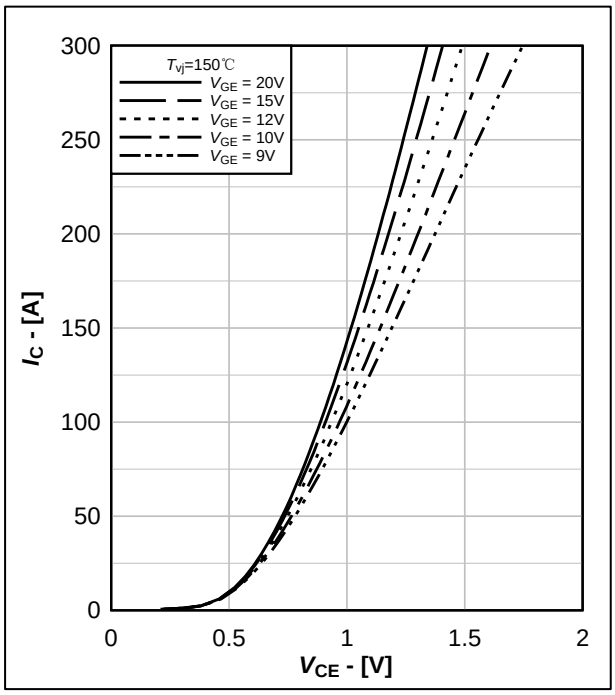


图 19. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.19 Typical IGBT output characteristic, I_C= f (V_{CE})

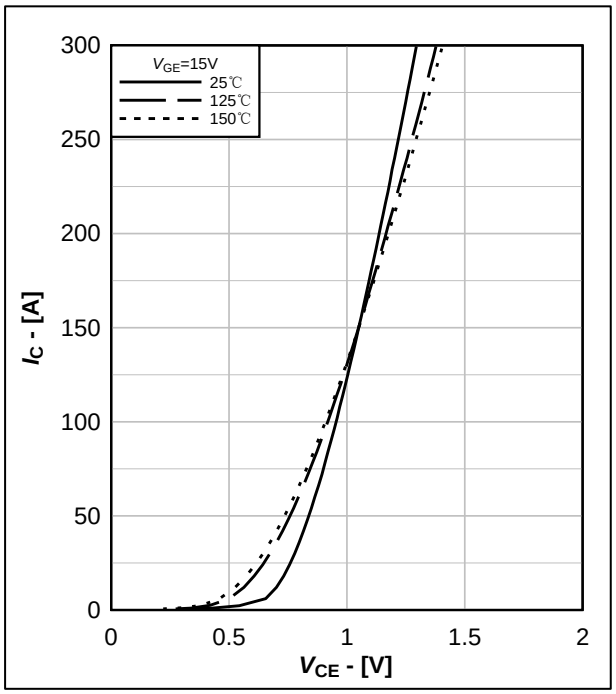


图 20. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.20 Typical IGBT output characteristic, I_C= f (V_{CE})

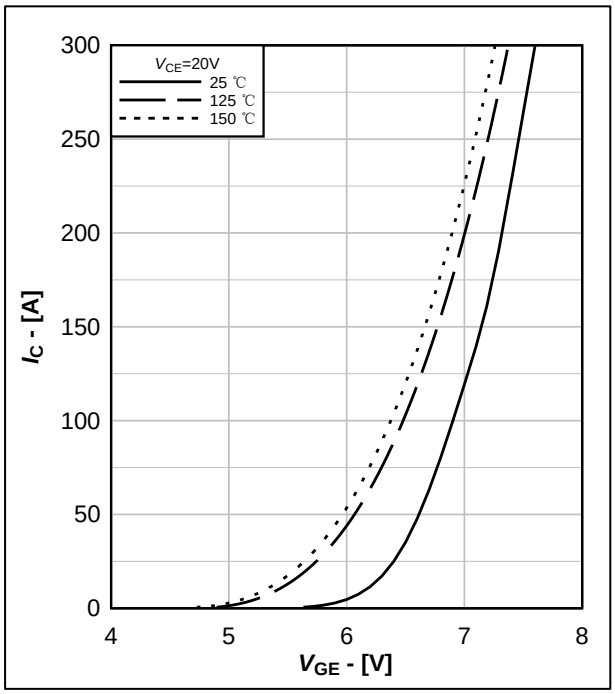


图 21. IGBT 传输特性典型曲线, I_C= f (V_{GE})

Fig.21 Typical IGBT transfer characteristic, I_C= f (V_{GE})

IGBT T2/T3，二极管 D2/D3　　IGBT T2/T3, Diode D2/D3

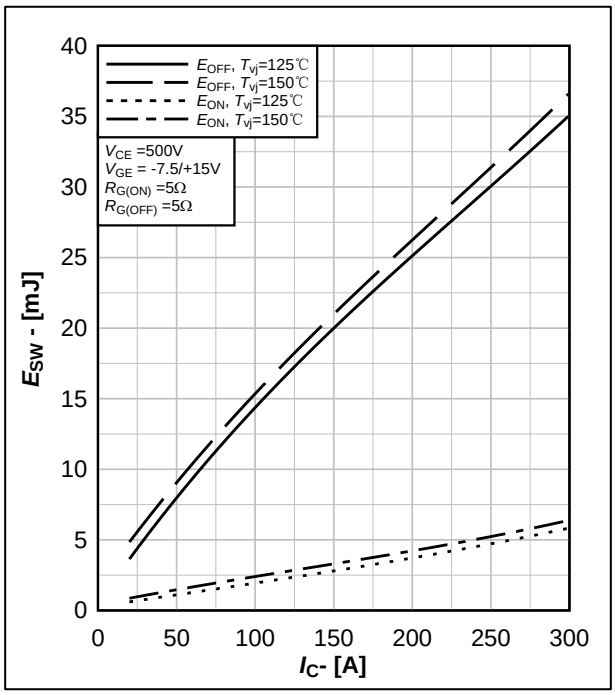


图 22. IGBT 开关损耗典型曲线, E_{on}= f (I_C), E_{off}= f (I_C)

Fig.22 Typical IGBT switching energy, E_{on}= f (I_C), E_{off}= f (I_C)

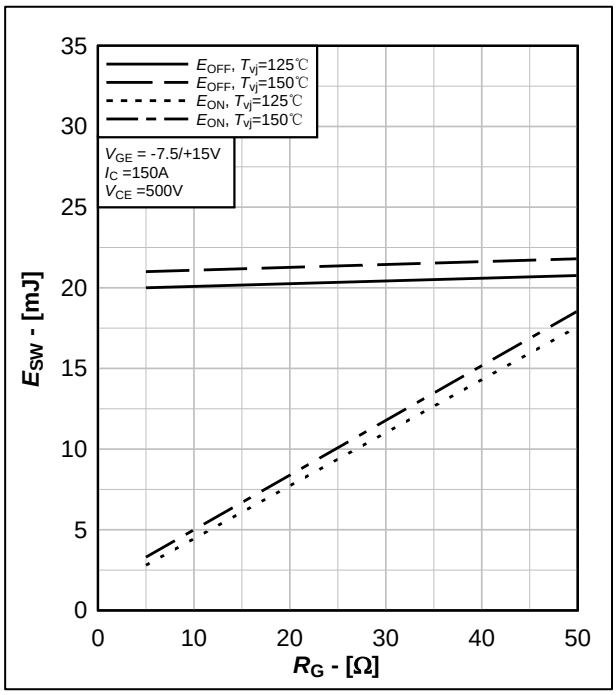


图 23. IGBT 开关损耗典型曲线, E_{on}= f (R_G), E_{off}= f (R_G)

Fig.23 Typical IGBT switching energy, E_{on}= f(R_G), E_{off}= f (R_G)

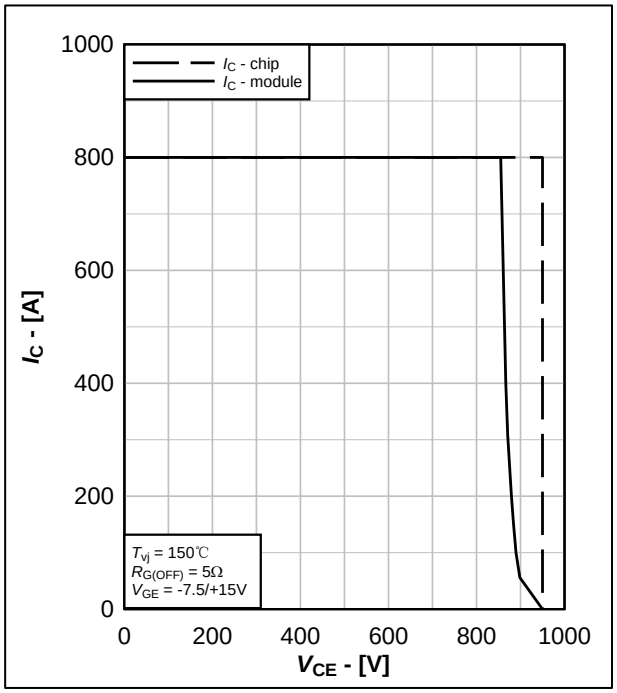


图 24. IGBT 反偏安全工作区, I_C = f (V_{CE})

Fig.24 Reverse bias safe operating area of IGBT, I_C = f (V_{CE})

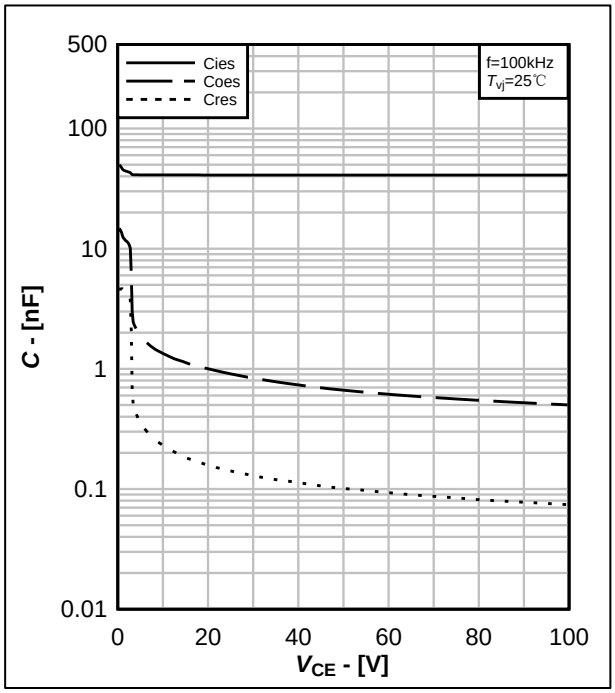


图 25. 电容特性典型曲线, C= f (V_{CE})

Fig.25 Typical capacity characteristic, C= f (V_{CE})

IGBT T2/T3，二极管 D2/D3　　IGBT T2/T3, Diode D2/D3

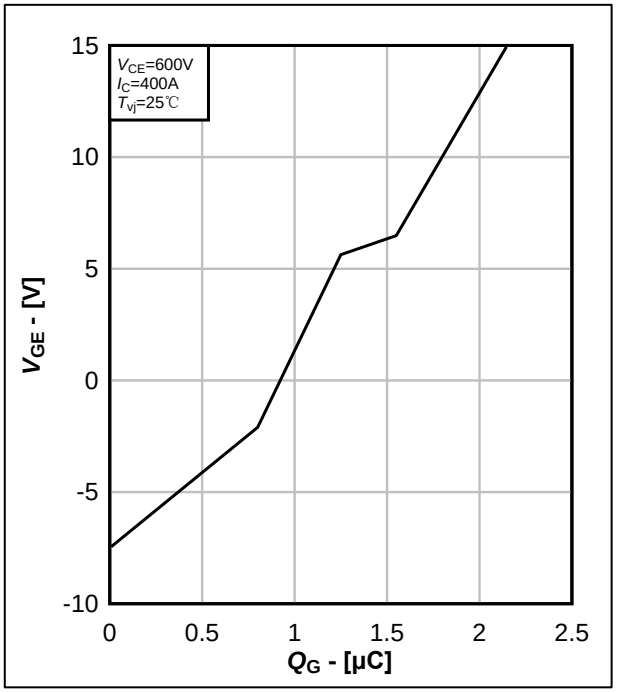


图 26. 栅极电荷特性典型曲线, V_{GE} = f (Q_G)

Fig.26 Typical gate charge characteristic, V_{GE}= f (Q_G)

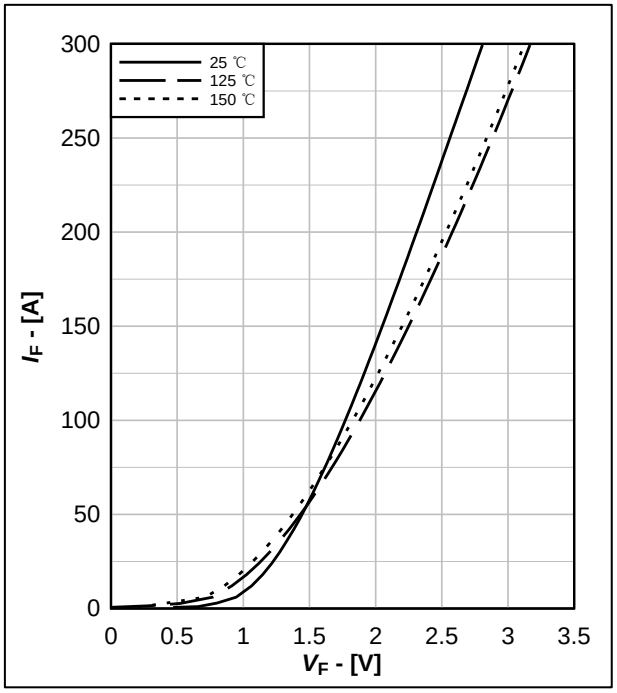


图 27. FRD 输出特性典型曲线, I_F = f (V_F)

Fig.27 Typical FRD output characteristic, I_F = f (V_F)

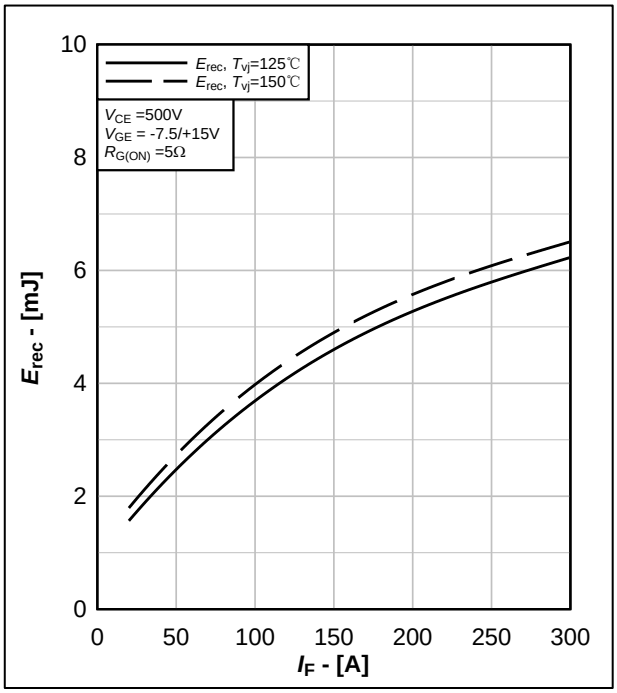


图 28. FRD 反向恢复损耗典型曲线, E_{rec}=f(I_F)

Fig.28 Typical FRD switching loss E_{rec}, E_{rec}=f(I_F)

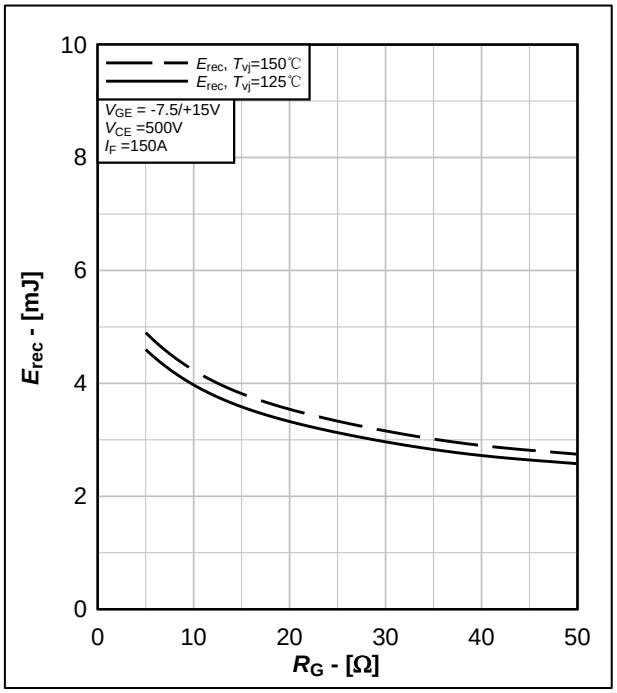


图 29. FRD 反向恢复损耗典型曲线, E_{rec}=f(R_G)

Fig.29 Typical FRD switching loss E_{rec}, E_{rec}=f(R_G)

IGBT T2/T3，二极管 D2/D3

IGBT T2/T3, Diode D2/D3

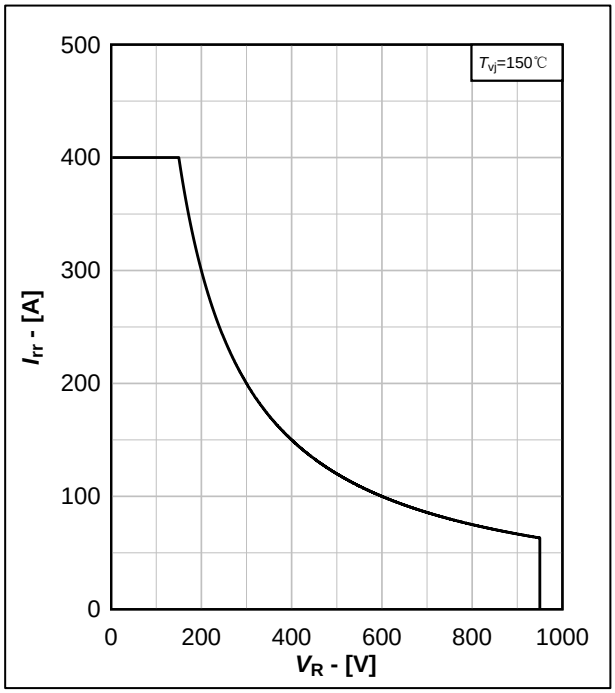


图 30. FRD 反偏安全工作区, I_{rr} = f (V_R)

Fig.30 Reverse bias safe operating area of FRD, I_{rr} = f (V_R)

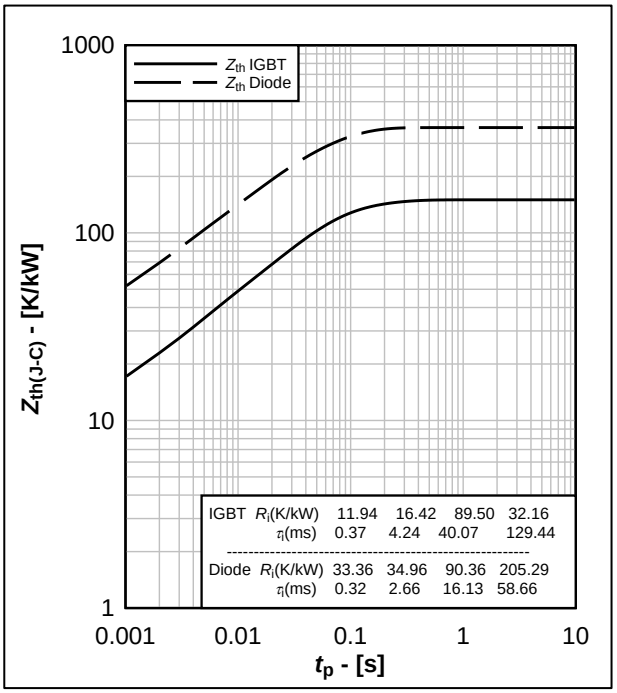


图 31. 瞬态热阻抗曲线, $Z_{th(J-C)}$ = f (t_p)

Fig.31 Transient thermal impedance, $Z_{th(J-C)}$ = f (t_p)

IGBT T5/T6，二极管 D5/D6

IGBT T5/T6, Diode D5/D6

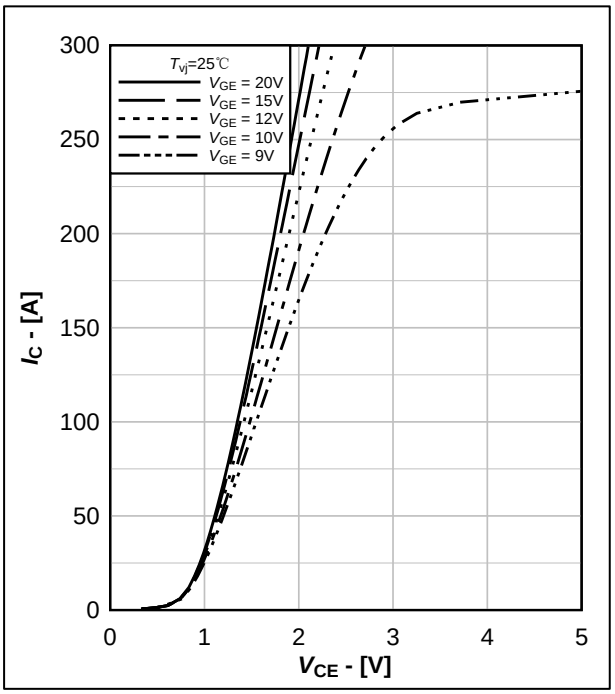


图 32. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.32 Typical IGBT output characteristic, I_C= f (V_{CE})

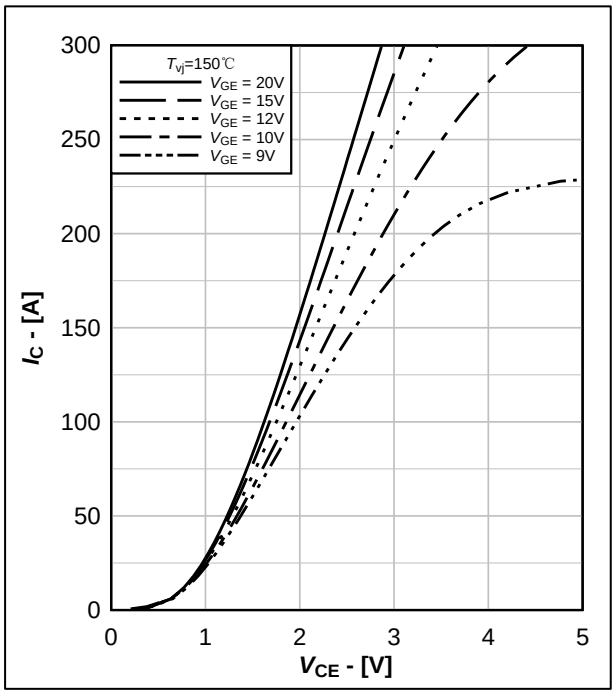


图 33. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.33 Typical IGBT output characteristic, I_C= f (V_{CE})

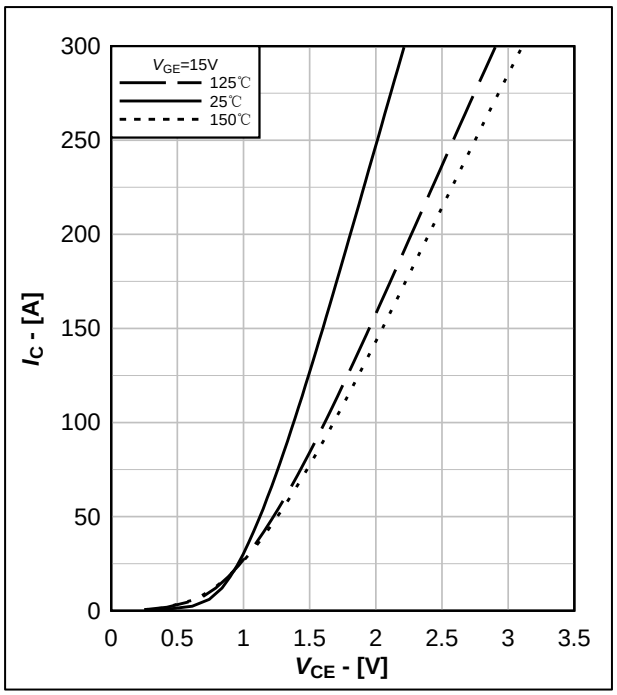


图 34. IGBT 输出特性典型曲线, I_C= f (V_{CE})

Fig.34 Typical IGBT output characteristic, I_C= f (V_{CE})

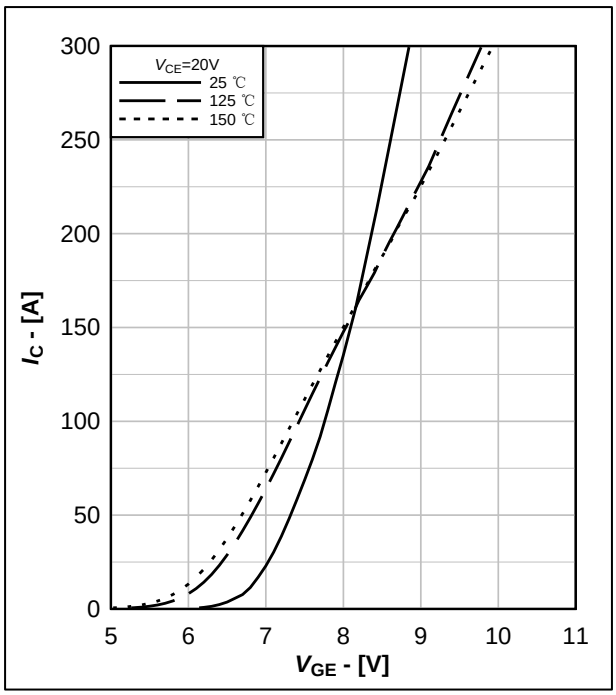


图 35. IGBT 传输特性典型曲线, I_C= f (V_{GE})

Fig.35 Typical IGBT transfer characteristic, I_C= f (V_{GE})

IGBT T5/T6，二极管 D5/D6　　IGBT T5/T6, Diode D5/D6

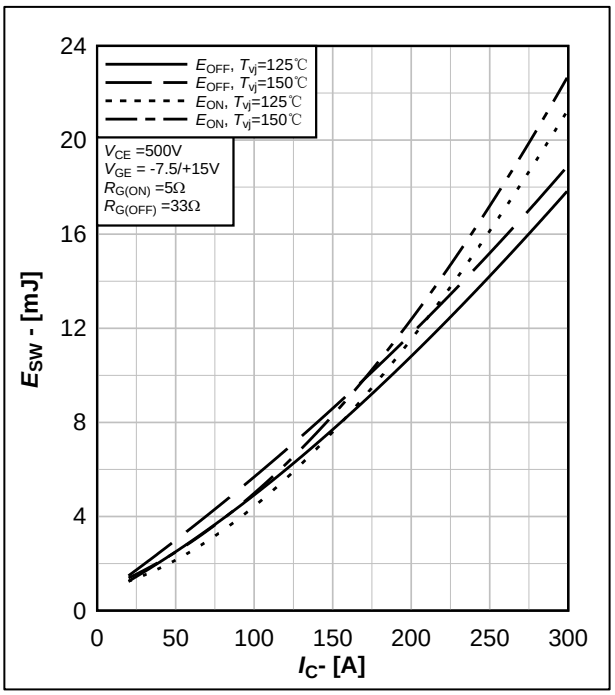


图 36. IGBT 开关损耗典型曲线, E_{on}= f (I_C), E_{off}= f (I_C)

Fig.36　Typical IGBT switching energy, E_{on}= f (I_C), E_{off}= f (I_C)

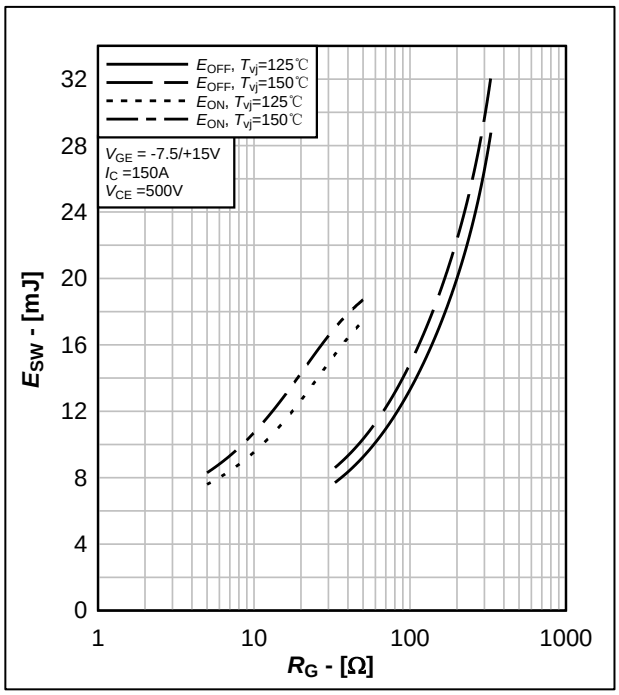


图 37. IGBT 开关损耗典型曲线, E_{on}= f (R_G), E_{off}= f (R_G)

Fig.37　Typical IGBT switching energy, E_{on}= f(R_G), E_{off}= f (R_G)

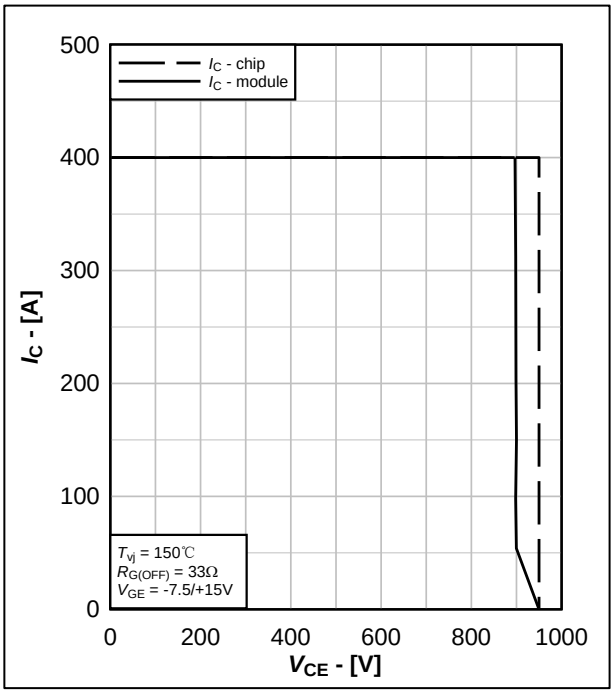


图 38. IGBT 反偏安全工作区, I_C = f (V_{CE})

Fig.38　Reverse bias safe operating area of IGBT, I_C = f (V_{CE})

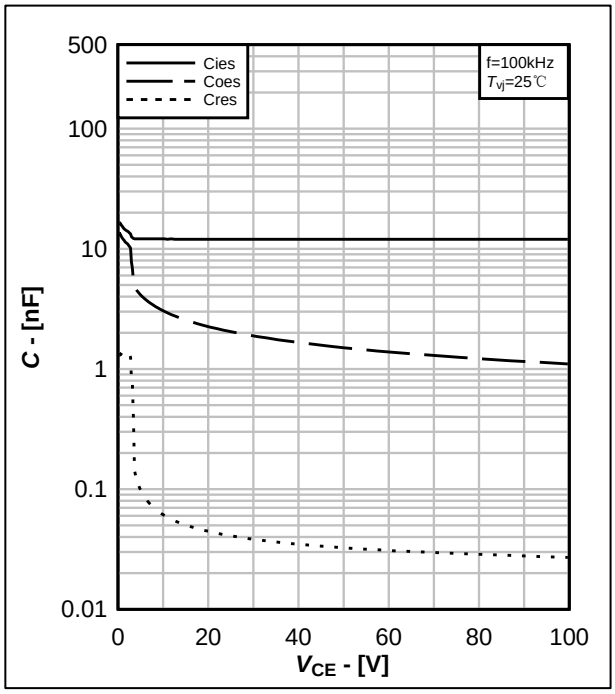


图 39. 电容特性典型曲线, C= f (V_{CE})

Fig.39　Typical capacity characteristic, C= f (V_{CE})

IGBT T5/T6，二极管 D5/D6

IGBT T5/T6, Diode D5/D6

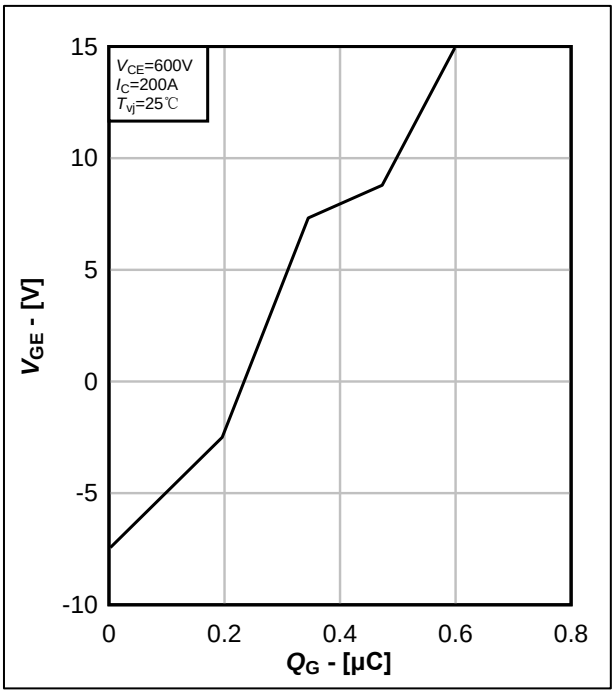


图 40. 栅极电荷特性典型曲线, V_{GE} = f (Q_G)

Fig.40 Typical gate charge characteristic, V_{GE}= f (Q_G)

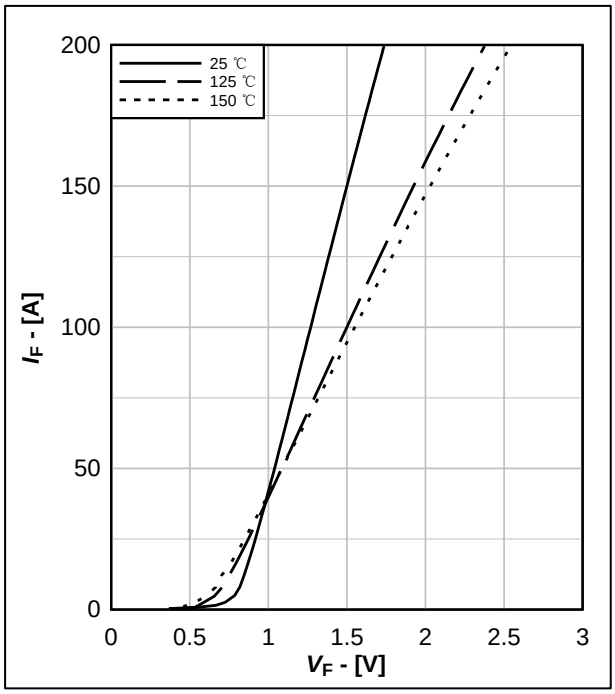


图 41. FRD 输出特性典型曲线, I_F = f (V_F)

Fig.41 Typical FRD output characteristic, I_F = f (V_F)

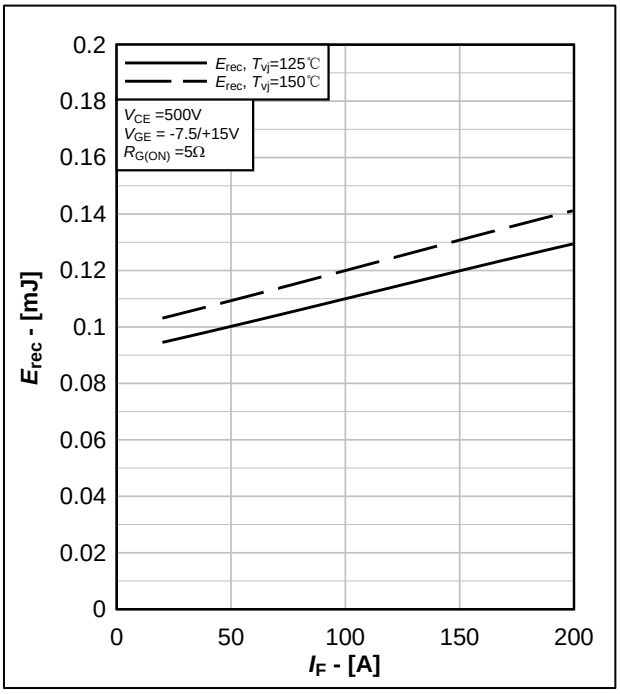


图 42. FRD 反向恢复损耗典型曲线, E_{rec}=f(I_F)

Fig.42 Typical FRD switching loss E_{rec}, E_{rec}=f(I_F)

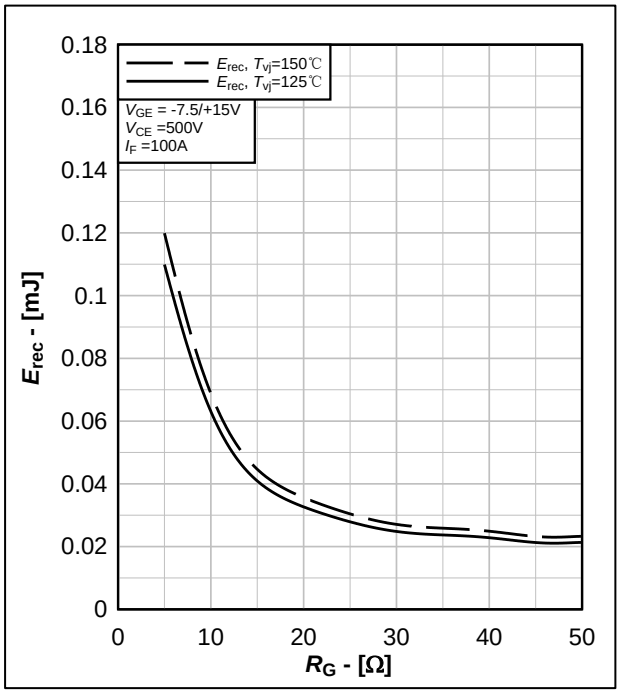


图 43. FRD 反向恢复损耗典型曲线, E_{rec}=f(R_G)

Fig.43 Typical FRD switching loss E_{rec}, E_{rec}=f(R_G)

IGBT T5/T6，二极管 D5/D6

IGBT T5/T6, Diode D5/D6

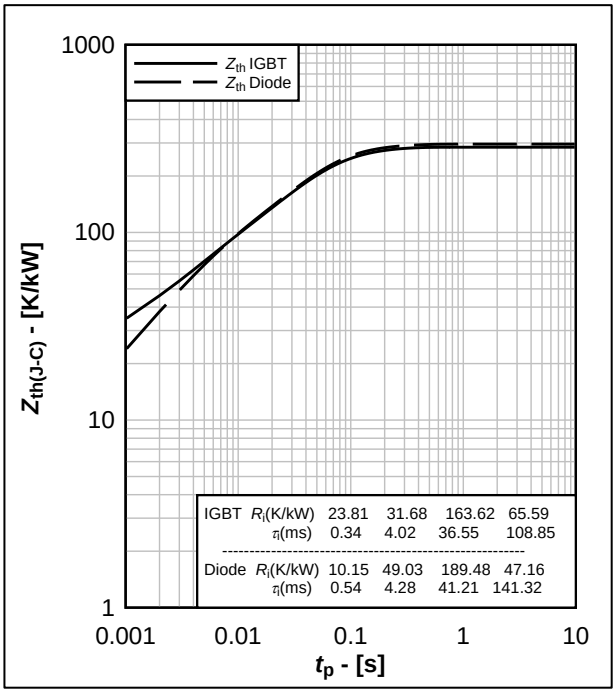
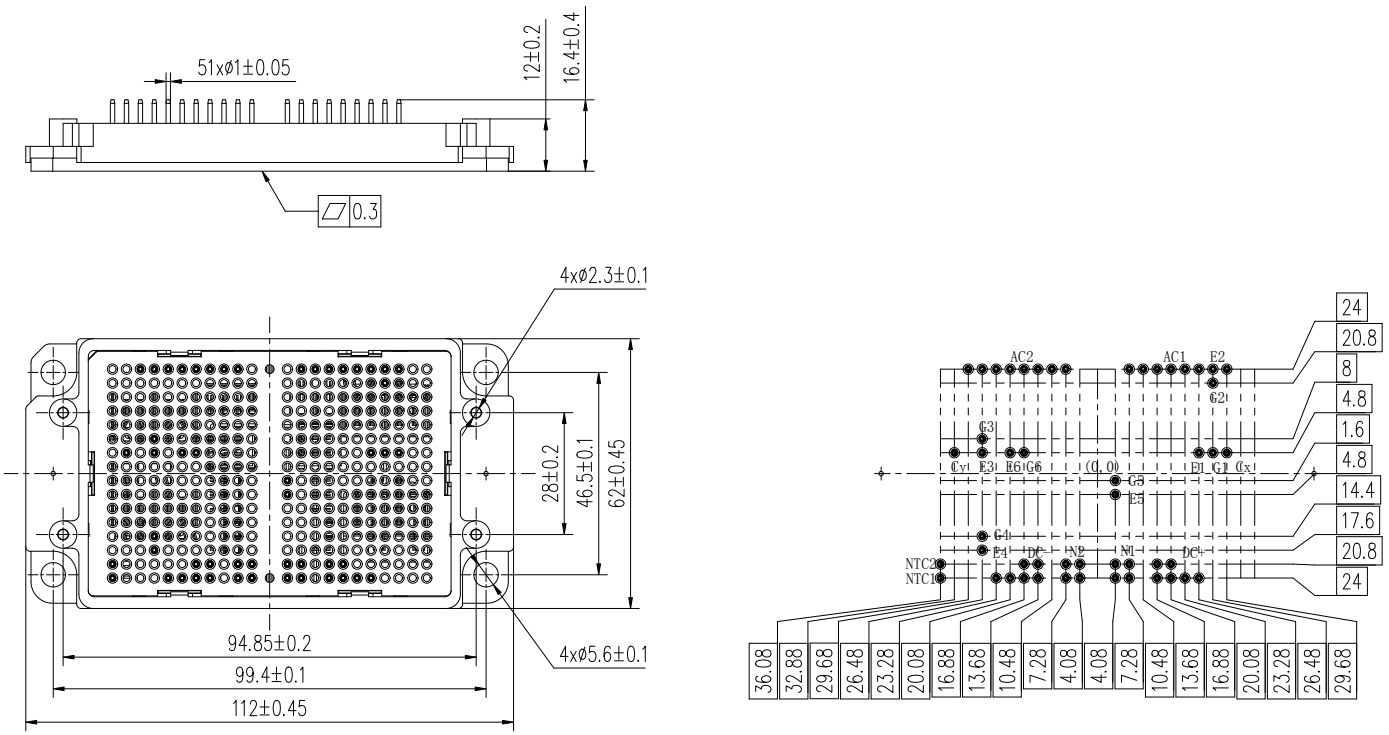


图 44. 瞬态热阻抗曲线, $Z_{th(J-C)} = f(t_p)$

Fig.44 Transient thermal impedance, $Z_{th(J-C)} = f(t_p)$



重量 Weight：104g 模块外观类型 Module outline code：U4

图 45. 模块外观尺寸

Fig. 45 Module outlines

株洲中车时代半导体有限公司

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