

**60A 650V Trench Fieldstop IGBT with anti-parallel diode**

**General Description**

The FRE60N065FSU2DG is a Field Stop Trench IGBT with anti-parallel diode, which offers ultra-low switching losses, high energy efficiency for switching applications such as PFC, Power Supply, Inverter, etc.

The FRE60N065FSU2DG package is TO-247.

**Symbol**

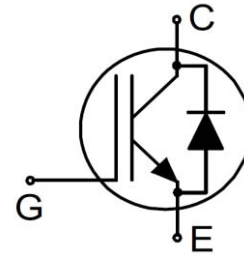
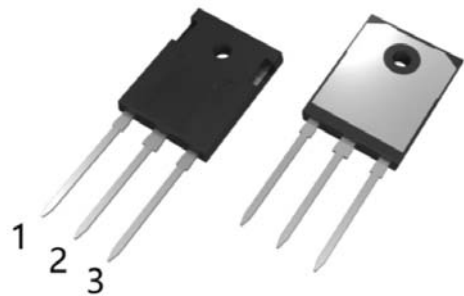


Figure 1 Symbol of FRE60N065FSU2DG

**Features**

- High Breakdown Voltage to 650V
- Advanced Trench Fieldstop technology
  - ▷ Smooth Switching Off with Lower Spike
  - ▷ High Ruggedness, Temperature Stability
  - ▷ Easy Parallel Switching Capability due to Positive Temperature Coefficient in  $V_{CE(SAT)}$
- Low  $V_{CE(SAT)}$
- Enhanced Avalanche Capability
- Non-Automotive Qualified

**Package Type**



TO-247

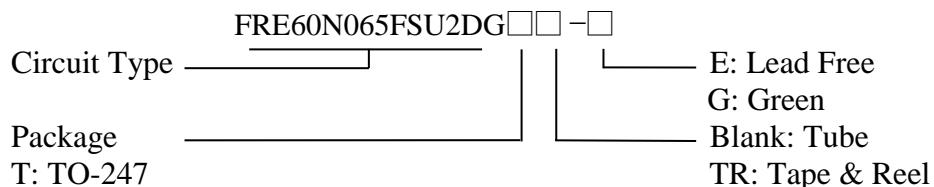
- Pin 1- gate
- Pin 2&backside-collector
- Pin 3-emitter

**Application**

- Inverter
- Uninterruptible power supplies
- PFC application
- Converter with high switching frequency

Figure 2 Package Type of FRE60N065FSU2DG

**Ordering Information**



Package	Part Number	Marking ID	Packing Type
	Green	Green	
TO-247	FRE60N065FSU2DGT-G1	SRE60N065FSU2DGTG1	Tube



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### Absolute Maximum Ratings

Parameter	Symbol	Rating	Unit	
Collector-emitter Voltage	$V_{CES}$	650	V	
Gate-emitter Voltage	$V_{GES}$	$\pm 20$	V	
Transient Gate-emitter Voltage		$\pm 30$	V	
Continuous Collector Current	$I_C$	$T_C=25^\circ\text{C}$	120	A
		$T_C=100^\circ\text{C}$	60	
Pulsed Collector Current, Limited by $T_{Jmax}$	$I_{CM}$	240	A	
Diode Continuous Collector Current	$I_F$	$T_C=25^\circ\text{C}$	70	A
		$T_C=100^\circ\text{C}$	40 <sup>(1)</sup>	
Diode Pulsed Current, Limited by $T_{Jmax}$	$I_{FM}$	120	A	
Power Dissipation	$P_{tot}$	$T_C=25^\circ\text{C}$	306	W
		$T_C=100^\circ\text{C}$	153	
Operating Junction Temperature Range	$T_J$	$-40 \sim 175^{(2)}$	$^\circ\text{C}$	
Storage Temperature Range	$T_{STG}$	$-55 \sim 150$	$^\circ\text{C}$	
Lead Temperature (Soldering, 10 sec)	$T_{LEAD}$	260	$^\circ\text{C}$	

Note:

1. Current level is limited by  $T_{j\_max}$ .
2. Reliability testing conducted at  $T_{Jmax}=175^\circ\text{C}$ .

### Thermal Resistance

Parameter	Symbol	Min.	Typ.	Max.	Unit
IGBT Thermal Resistance, Junction-to-Case	$R_{thJC}$	-	-	0.49	$^\circ\text{C}/\text{W}$
Diode Thermal Resistance, Junction-to-Case	$R_{thJC}$	-	-	1.0	
Thermal Resistance, Junction-to-Ambient	$R_{thJA}$	-	-	40	



60A 650V Trench Fieldstop IGBT with anti-parallel diode

Electrical Characteristics

T<sub>J</sub> = 25°C, unless otherwise specified.

Parameter		Symbol	Test Conditions	Min.	Typ.	Max.	Unit	
<b>Statistic Characteristics</b>								
Collector-emitter Voltage	Breakdown	BV <sub>CES</sub>	V <sub>GE</sub> =0V, I <sub>C</sub> =250μA	650			V	
Gate Threshold Voltage		V <sub>GE(th)</sub>	V <sub>CE</sub> =V <sub>GE</sub> , I <sub>C</sub> =250μA	3.8	4.8	5.8	V	
Collector-emitter saturation voltage		V <sub>CEsat</sub>	V <sub>GE</sub> =15V, I <sub>C</sub> =60A, T <sub>J</sub> =25°C		1.51	2.0	V	
			T <sub>J</sub> =125°C		1.81		V	
			T <sub>J</sub> =150°C		1.92		V	
Zero Gate Voltage Collector Current		I <sub>CES</sub>	V <sub>CE</sub> =650V, V <sub>GE</sub> =0V T <sub>J</sub> =25°C		0.1	40	μA	
			T <sub>J</sub> =150°C			1	mA	
Gate-emitter Leakage Current	Forward	I <sub>GESF</sub>	V <sub>GE</sub> =20V, V <sub>CE</sub> =0V			100	nA	
	Reverse	I <sub>GESR</sub>	V <sub>GE</sub> =-20V, V <sub>CE</sub> =0V			-100	nA	
<b>Dynamic Characteristics</b>								
Input Capacitance		C <sub>IES</sub>	V <sub>CE</sub> =25V, V <sub>GE</sub> =0V, f=1 MHz		2350		pF	
Output Capacitance		C <sub>OES</sub>			220			
Reverse Transfer Capacitance		C <sub>RES</sub>			25			
Gate Resistance		R <sub>G</sub>	f=1 MHz, Open Drain		1.7		Ω	
Turn-on Delay Time		t <sub>d(on)</sub>	T <sub>J</sub> =25°C V <sub>CC</sub> =400V, I <sub>C</sub> =60A R <sub>G</sub> =10Ω, V <sub>GE</sub> =0/15V		21		ns	
Rise Time		t <sub>r</sub>			38		ns	
Turn-off Delay Time		t <sub>d(off)</sub>			122		ns	
Fall Time		t <sub>f</sub>			70		ns	
Turn-on energy		E <sub>on</sub>			1.34		mJ	
Turn-off energy		E <sub>off</sub>			0.63		mJ	
Total switching energy		E <sub>ts</sub>			1.97		mJ	
Turn-on Delay Time		t <sub>d(on)</sub>		T <sub>J</sub> =150°C V <sub>CC</sub> =400V, I <sub>C</sub> =60A R <sub>G</sub> =10Ω, V <sub>GE</sub> =0/15V		18		ns
Rise Time		t <sub>r</sub>				39		ns
Turn-off Delay Time		t <sub>d(off)</sub>				149		ns
Fall Time		t <sub>f</sub>			118		ns	
Turn-on energy		E <sub>on</sub>			2.43		mJ	
Turn-off energy		E <sub>off</sub>			0.92		mJ	
Total switching energy		E <sub>ts</sub>			3.35		mJ	
Gate to Emitter Charge		Q <sub>GE</sub>	V <sub>CC</sub> =400V, I <sub>C</sub> =60A V <sub>GE</sub> =0 to 15V			28		nC
Gate to Collector Charge		Q <sub>GC</sub>			91			
Gate Charge Total		Q <sub>G</sub>			190			



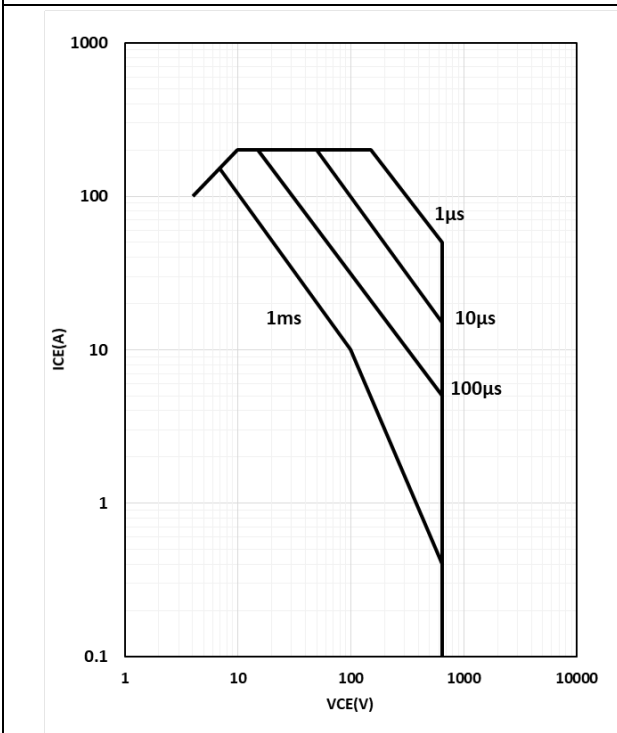
60A 650V Trench Fieldstop IGBT with anti-parallel diode

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
<b>Reverse Diode Characteristics</b>						
Drain-Source Diode Forward Voltage	V <sub>F</sub>	V <sub>GE</sub> =0V, I <sub>F</sub> =30A T <sub>J</sub> =25°C		1.61	1.89	V
		V <sub>GE</sub> =0V, I <sub>F</sub> =30A T <sub>J</sub> =125°C		1.44		
		V <sub>GE</sub> =0V, I <sub>F</sub> =30A T <sub>J</sub> =150°C		1.39		
		V <sub>GE</sub> =0V, I <sub>F</sub> =60A T <sub>J</sub> =25°C		1.79	2.22	V
		V <sub>GE</sub> =0V, I <sub>F</sub> =60A T <sub>J</sub> =125°C		1.69		
		V <sub>GE</sub> =0V, I <sub>F</sub> =60A T <sub>J</sub> =150°C		1.65		
Reverse Recovery Time	t <sub>rr</sub>	T <sub>J</sub> =25°C V <sub>R</sub> =400V, I <sub>F</sub> =30A dI <sub>F</sub> /dt=1100A/us		130		ns
Reverse Recovery Charge	Q <sub>rr</sub>			0.72		uC
Peak Reverse Recovery Current	I <sub>rrm</sub>			18		A
Diode peak rate of fall of reverse Recovery current during tb	dI <sub>rr</sub> /dt			-456		A/us
Reverse Recovery Time	t <sub>rr</sub>	T <sub>J</sub> =25°C V <sub>R</sub> =400V, I <sub>F</sub> =60A dI <sub>F</sub> /dt=1000A/us		179		ns
Reverse Recovery Charge	Q <sub>rr</sub>			0.84		uC
Peak Reverse Recovery Current	I <sub>rrm</sub>			19		A
Diode peak rate of fall of reverse Recovery current during tb	dI <sub>rr</sub> /dt			-375		A/us
Reverse Recovery Time	t <sub>rr</sub>	T <sub>J</sub> =150°C V <sub>R</sub> =400V, I <sub>F</sub> =30A dI <sub>F</sub> /dt=1100A/us		143		ns
Reverse Recovery Charge	Q <sub>rr</sub>			1.34		nC
Peak Reverse Recovery Current	I <sub>rrm</sub>			25		A
Diode peak rate of fall of reverse Recovery current during tb	dI <sub>rr</sub> /dt			-523		A/us
Reverse Recovery Time	t <sub>rr</sub>	T <sub>J</sub> =150°C V <sub>R</sub> =400V, I <sub>F</sub> =60A dI <sub>F</sub> /dt=1000A/us		223		ns
Reverse Recovery Charge	Q <sub>rr</sub>			1.93		uC
Peak Reverse Recovery Current	I <sub>rrm</sub>			26		A
Diode peak rate of fall of reverse Recovery current during tb	dI <sub>rr</sub> /dt			-394		A/us

## 60A 650V Trench Fieldstop IGBT with anti-parallel diode

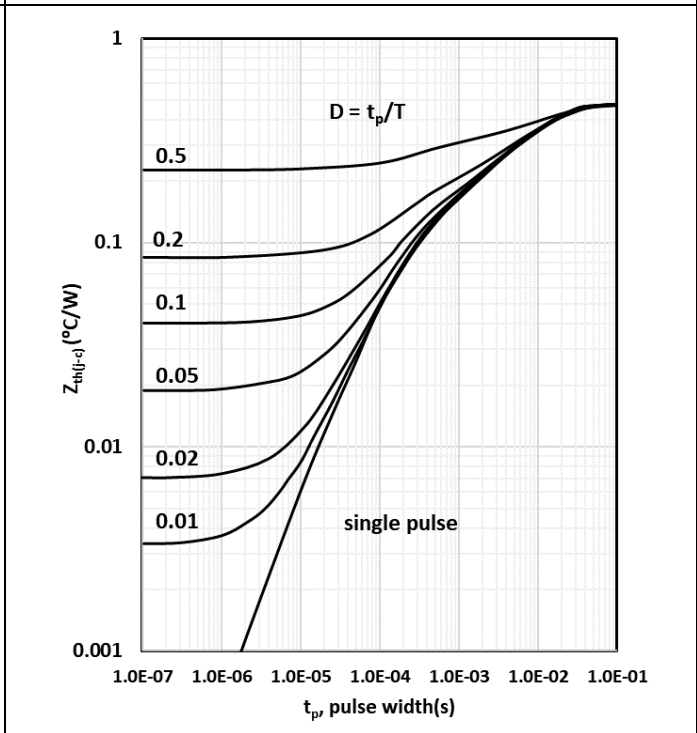
### Typical Performance Characteristics

Figure 3: IGBT FBSOA



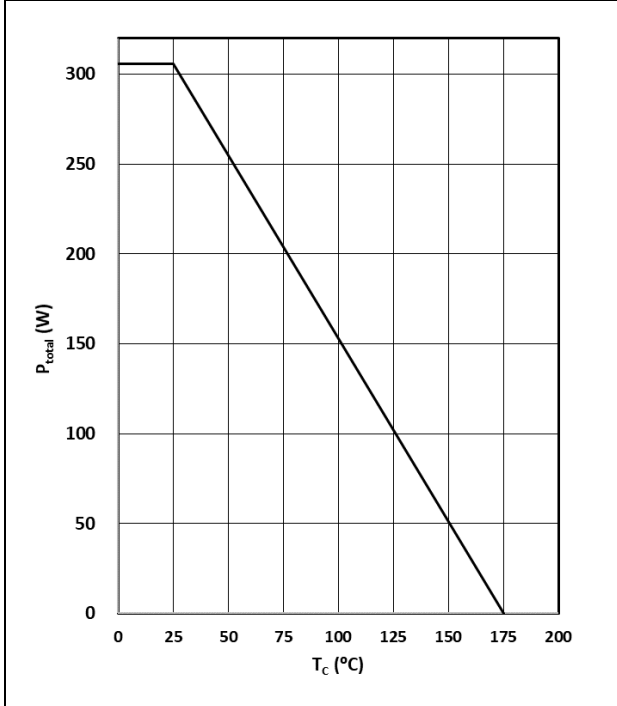
$I_C = f(V_{CE})$ ;  $V_{GE} \geq 15/0V$ ;  $T_j \leq 175^\circ C$

Figure 4: IGBT transient thermal impedance



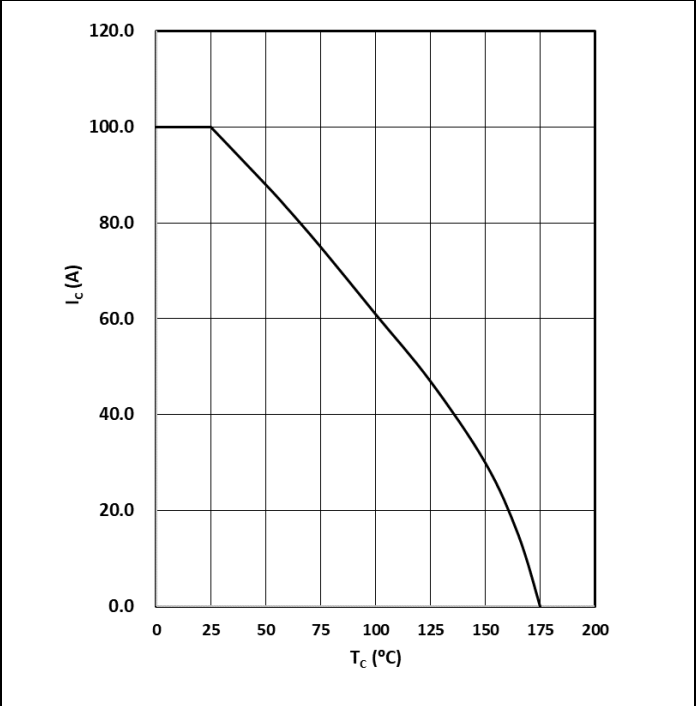
$R_{th(j-c)} = f(t_p)$ ; duty cycle:  $D = t_p/T$

Figure 5: Power dissipation



$P_{tot} = f(T_c)$ ;

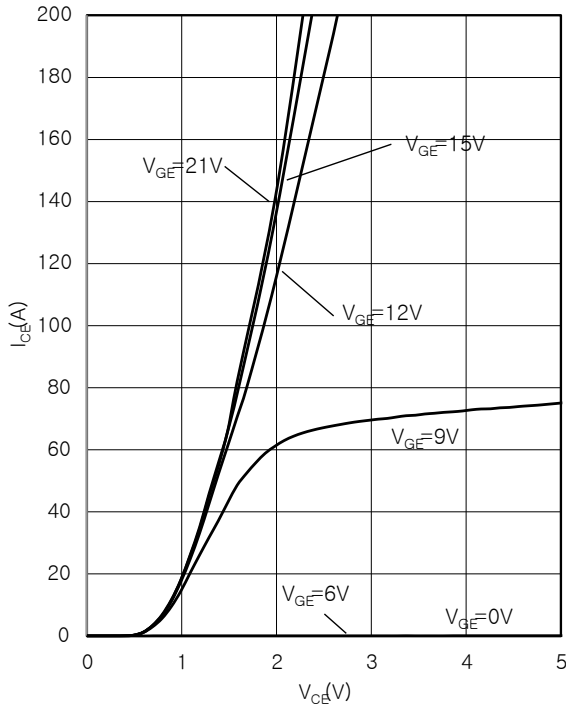
Figure 6: Collector current vs. temperature



$I_c = f(T_j)$ ;  $V_{GE} \geq 15V$ ;  $T_j \leq 175^\circ C$

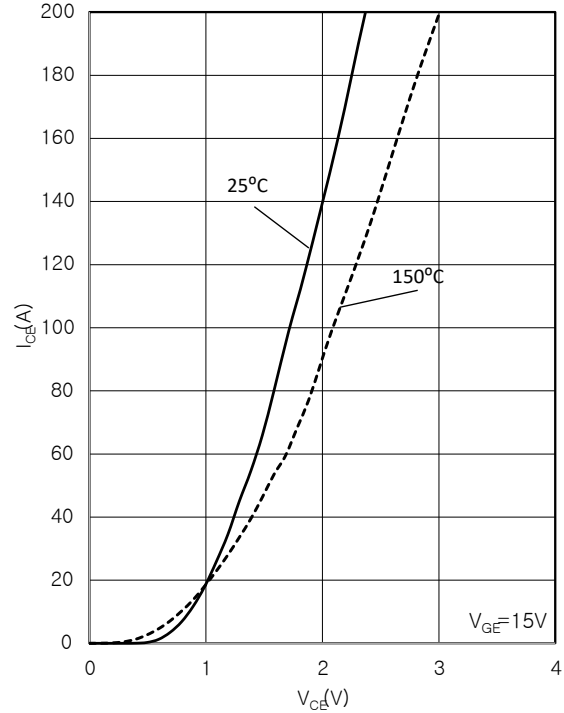
## 60A 650V Trench Fieldstop IGBT with anti-parallel diode

Figure 7: Typ. Output Characteristics



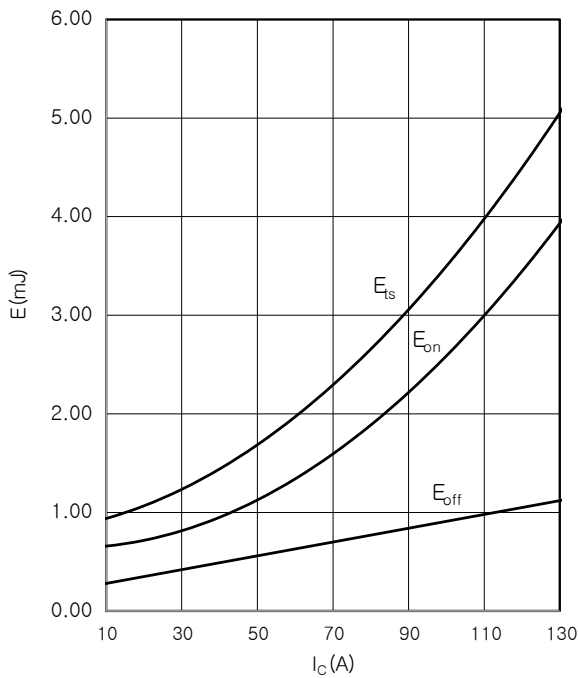
$I_C = f(V_{CE})$ ;  $T_j = 25^\circ\text{C}$ ; parameter:  $V_{GE}$

Figure 8: Saturation Voltage Characteristics



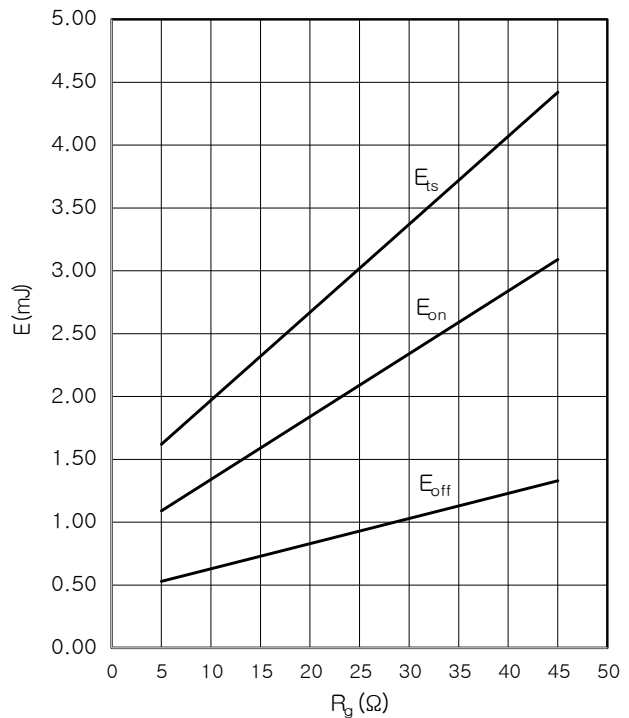
$I_C = f(V_{CE})$ ;  $T_j = 25^\circ\text{C}$  vs  $150^\circ\text{C}$

Figure 9: IGBT switching energy losses



$E = f(I_C)$ ;  $V_{CE} = 400\text{V}$ ;  $T_j = 25^\circ\text{C}$ ;  $R_G = 10\Omega$

Figure 10: IGBT switching energy losses



$E = f(R_G)$ ;  $V_{CE} = 400\text{V}$ ;  $T_j = 25^\circ\text{C}$ ;  $I_C = 60\text{A}$

## 60A 650V Trench Fieldstop IGBT with anti-parallel diode

Figure 11: Typ. Collector Voltage vs. Temperature

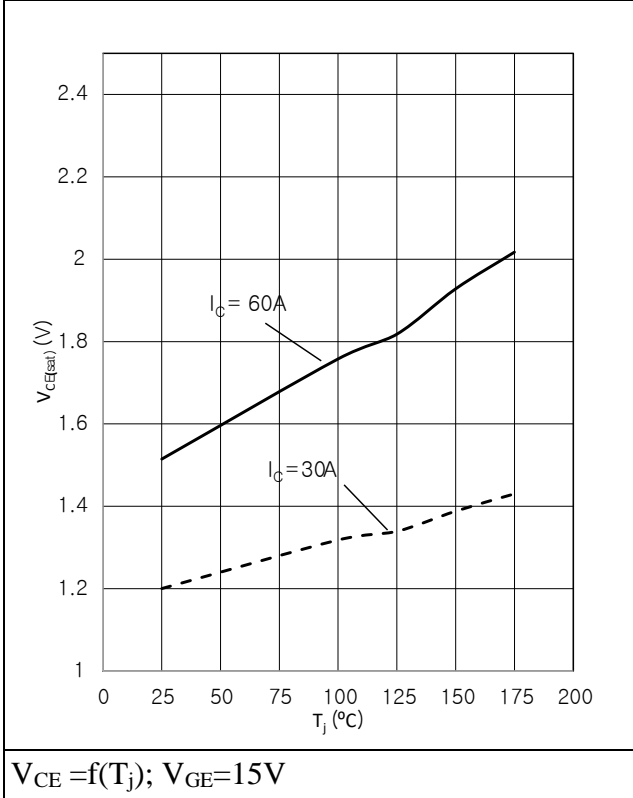


Figure 12: Typ. emitter threshold voltage as a function of junction temperature

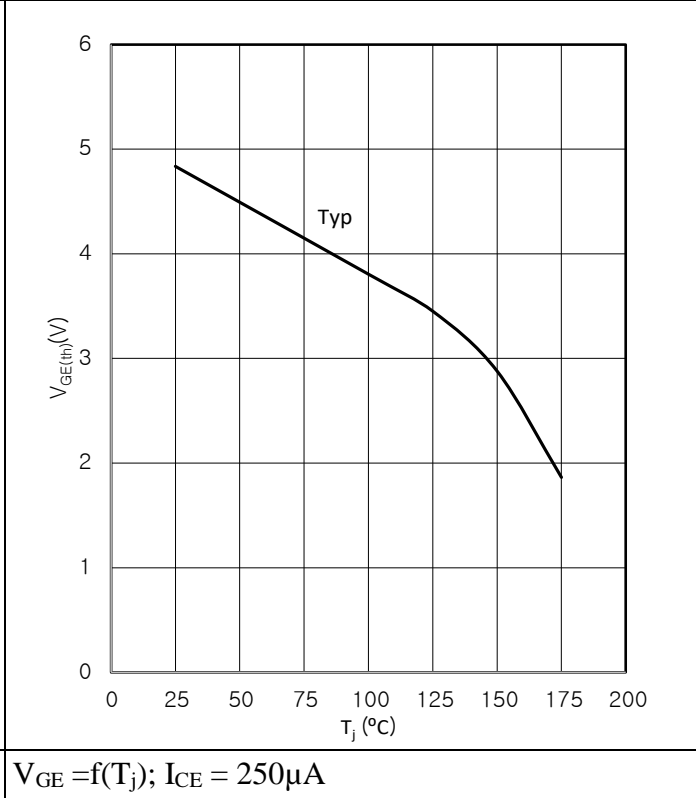


Figure 13: Typ. Gate Charge

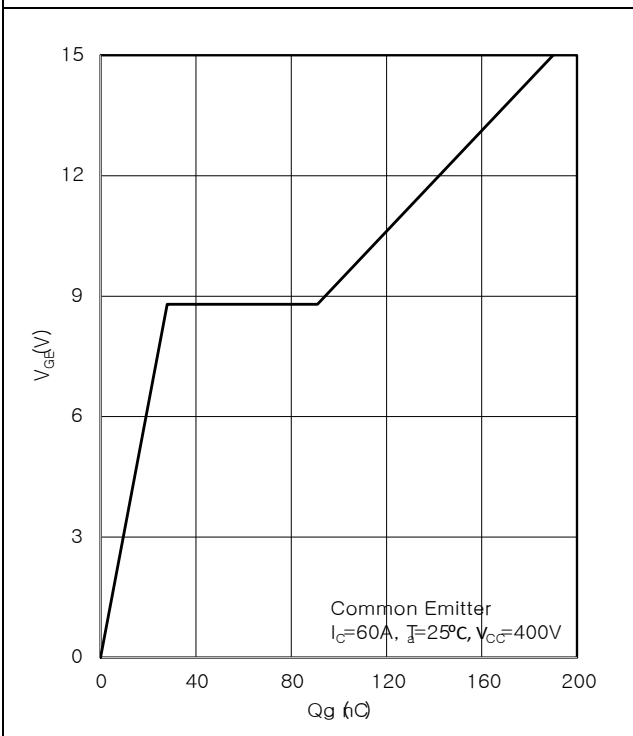
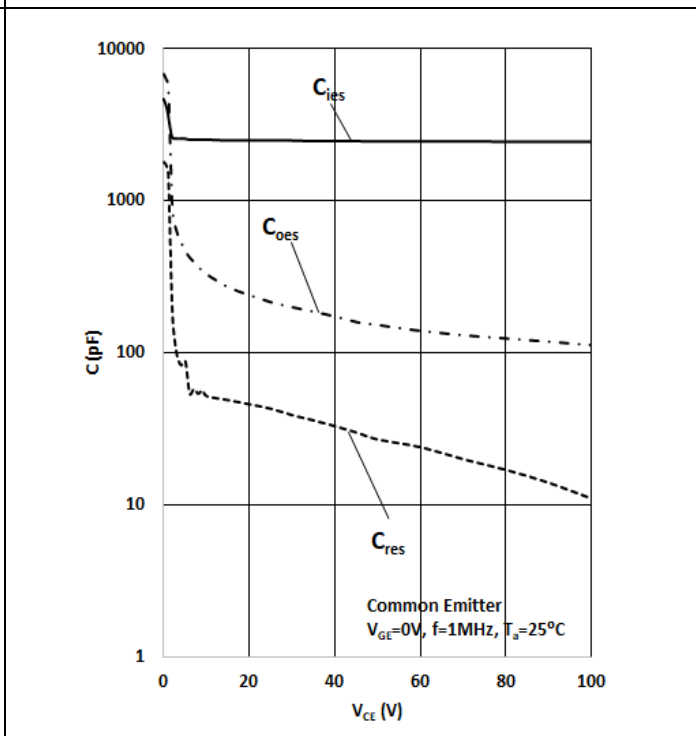


Figure 14: Typ. Capacitances

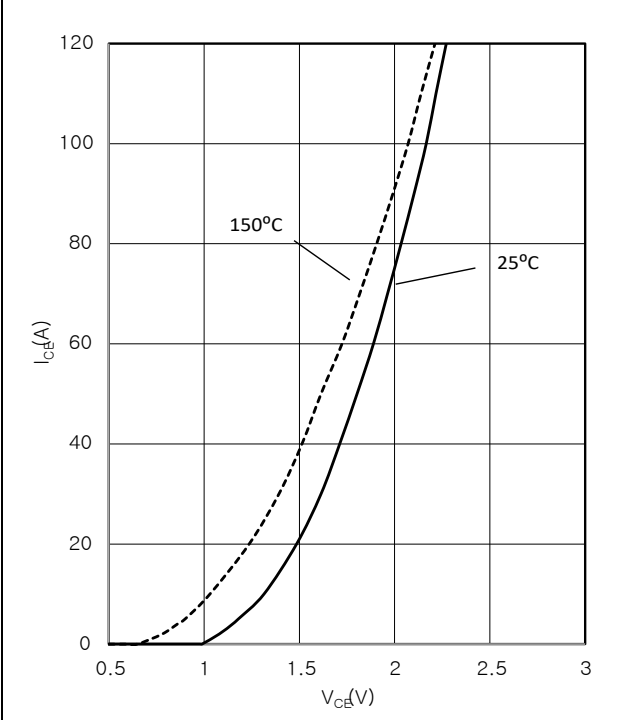




# FRE60N065FSU2DGT

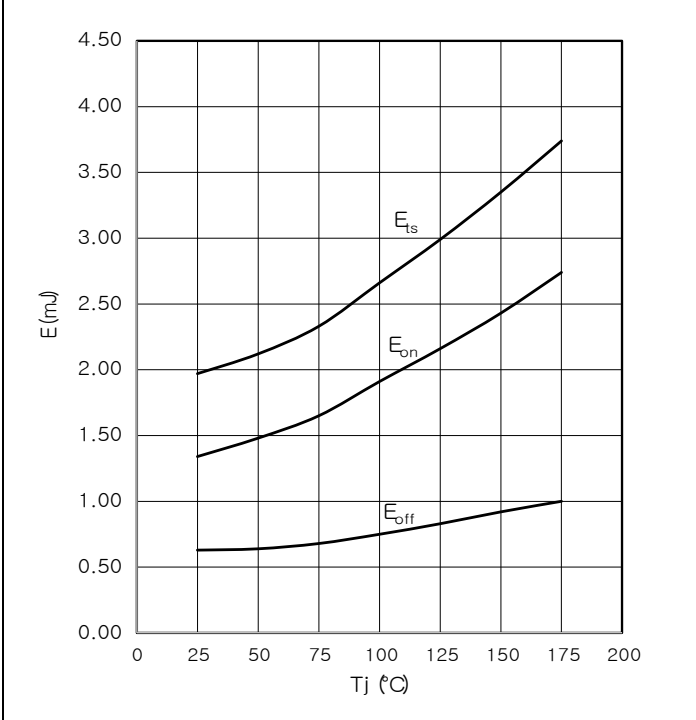
## 60A 650V Trench Fieldstop IGBT with anti-parallel diode

Figure 15: Typ. diode forward current as a function of forward voltage



$I_F = f(V_{EC});$

Figure 16: IGBT switching energy losses



$E = f(T_j); V_{CE} = 400V; I_c = 60A; R_G = 10\Omega$

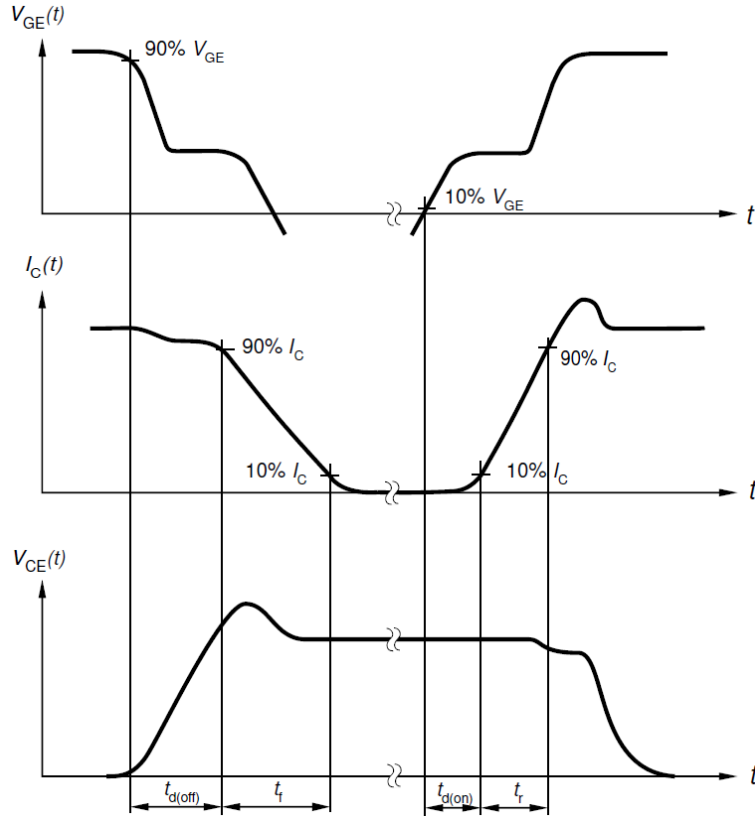




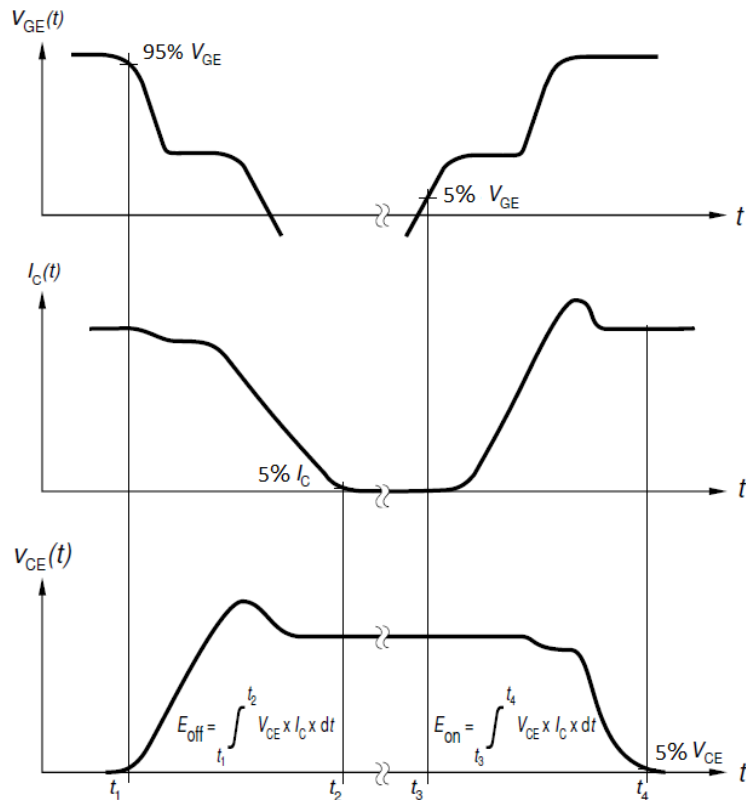
# 60A 650V Trench Fieldstop IGBT with anti-parallel diode

## Test Circuits

### 1. Definition Switching times

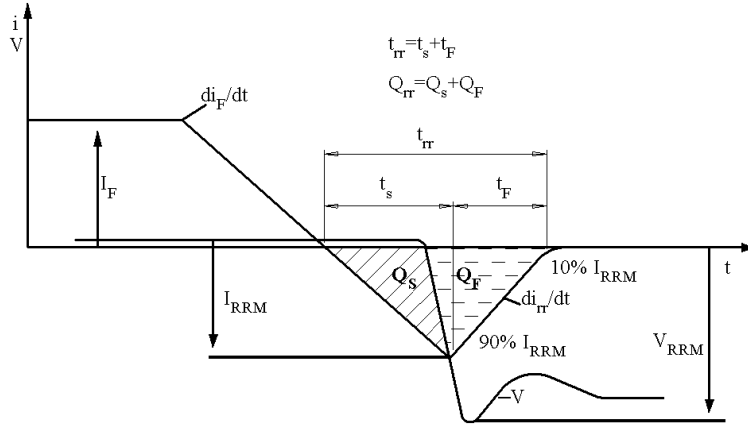


### 2. Definition Switching losses

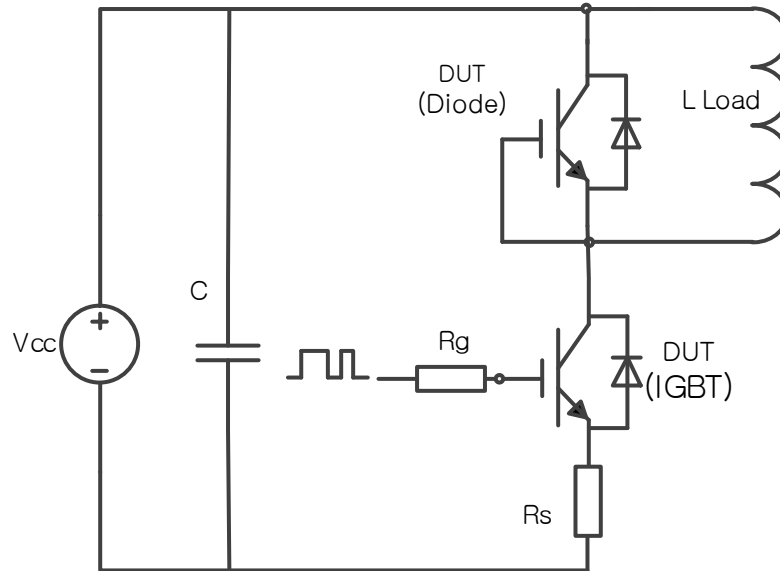


## 60A 650V Trench Fieldstop IGBT with anti-parallel diode

### 3. Definition Diode Switching Characteristics



### 4. Dynamic test circuit





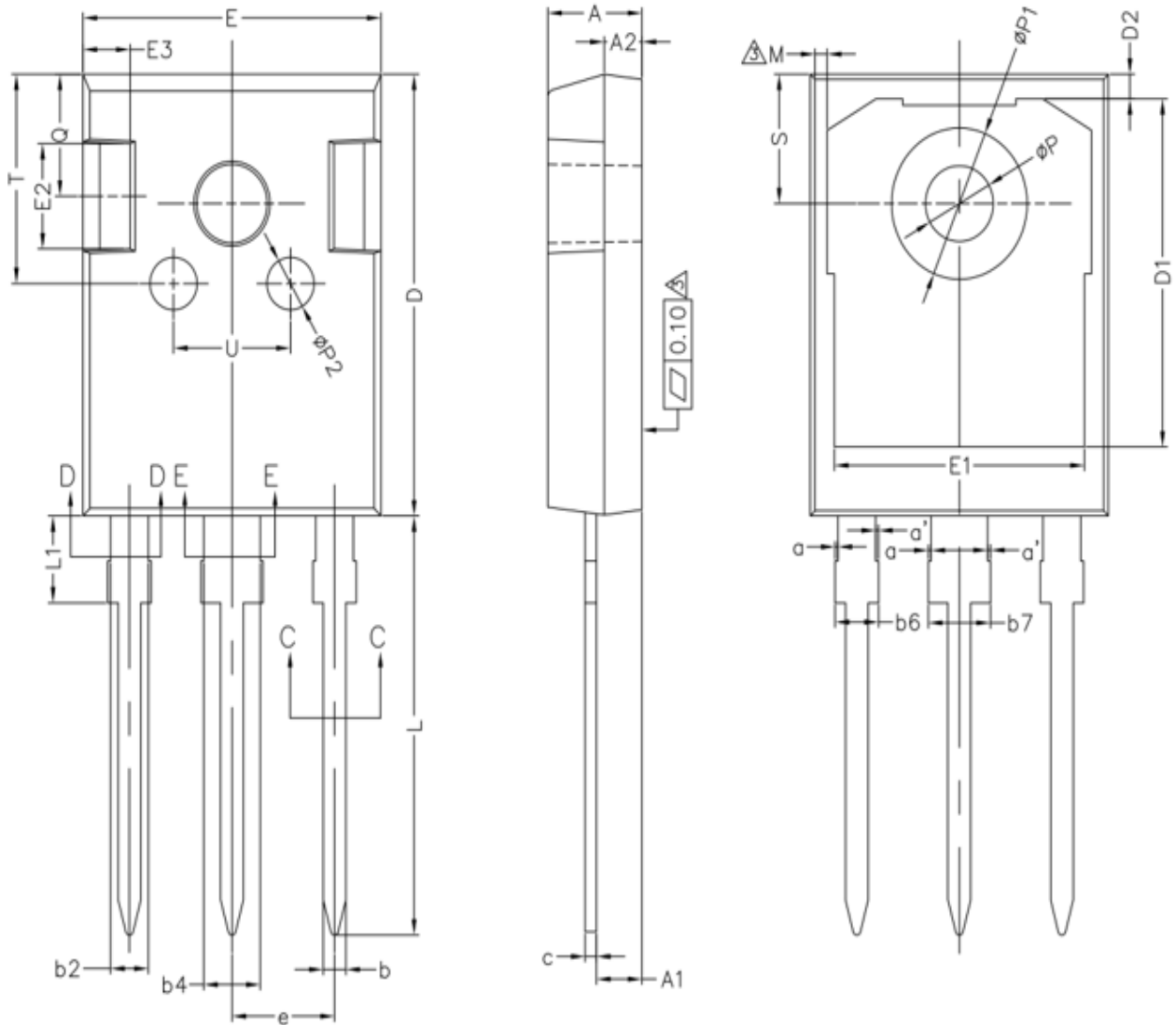
# FRE60N065FSU2DGT

## 60A 650V Trench Fieldstop IGBT with anti-parallel diode

### Mechanical Dimensions

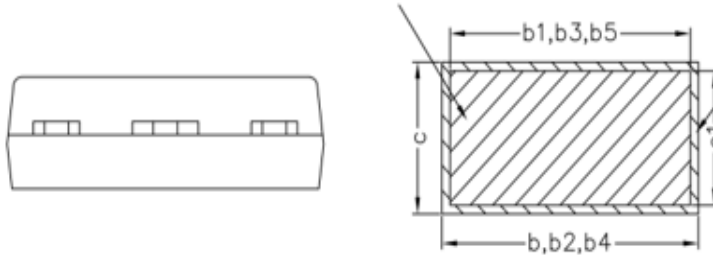
TO-247

Unit: mm



BASE METAL

WITH PLATING





# FRE60N065FSU2DGT

## 60A 650V Trench Fieldstop IGBT with anti-parallel diode

### Mechanical Dimensions

Symbol	Dimensions(mm)			Symbol	Dimensions(mm)		
	Min.	Typ.	Max.		Min.	Typ.	Max.
A	4.90	5.00	5.10	D2	1.05	1.20	1.35
A1	2.31	2.41	2.51	E	15.70	15.80	15.90
A2	1.90	2.00	2.10	E1	13.10	13.30	13.50
a	0	-	0.15	E2	4.90	5.00	5.10
a'	0	-	0.15	E3	2.40	2.50	2.60
b	1.16	-	1.26	e	5.34	5.44	5.54
b1	1.15	1.2	1.22	L	19.80	19.92	20.10
b2	1.96	-	2.06	L1	-	-	4.30
b3	1.95	2.00	2.02	M	0.35	-	0.95
b4	2.96	-	3.06	P	3.50	3.60	3.70
b5	2.95	3.00	3.02	P1	7.00	-	7.40
b6	-	-	2.25	P2	2.40	2.50	2.60
b7	-	-	3.25	Q	5.60	-	6.00
c	0.59	-	0.66	S	6.05	6.15	6.25
c1	0.58	0.60	0.62	T	9.80	-	10.20
D	20.90	21.00	21.10	U	6.00	-	6.40
D1	16.25	16.55	16.85	-	-	-	-