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Introduction of CRRC IGBT

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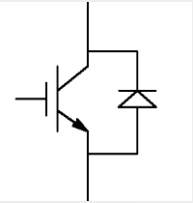
Contents

Part 1 Brief Instruction of IGBT

- **IGBT**, a power semiconductor device that can be turned on or off by adjusting gate voltage;
- Withstand voltage during off state but cannot withstand voltage in reverse direction;
- Anti-parallel FRDs connected;
- Asymmetry voltage blocking and reverse current conducting;
- Mainly used for DC-AC application;
- With technology development, PWM AC-DC rectifier applications are becoming more widespread.

Comparison

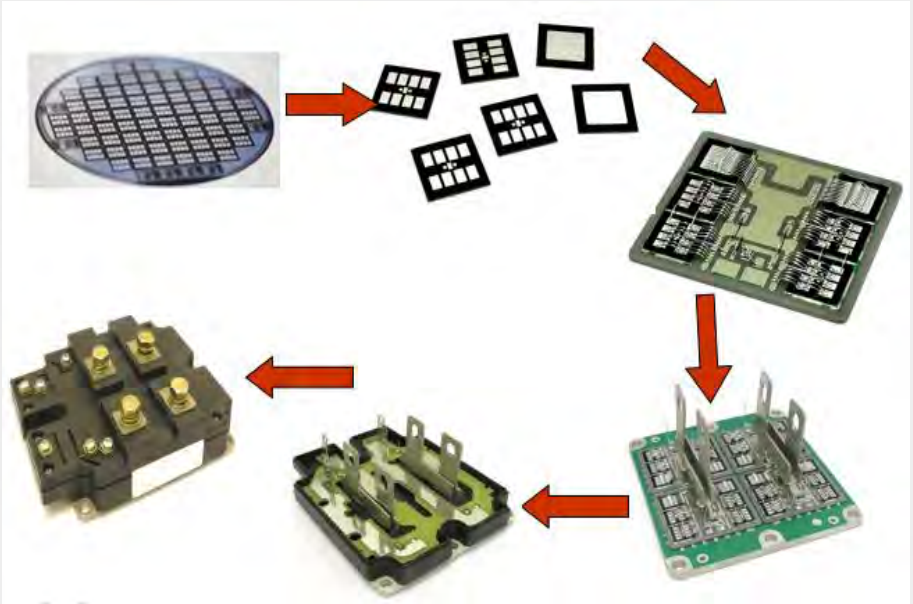
- Mechanical switch: switching speed ms level, life expectancy around 100,000 operation times;
- IGBT: Switching speed us level, frequency up mto tens of kHz, lifetime more than years.



Part 1 Brief Instruction of IGBT

Module Packaging Flow

- Dicing dies from processed IGBT wafer;
- Soldering dies onto substrate, all the dies connected via wire bonding;
- Welding substrates onto baseplate, soldering the connecting busbars;
- Adding a frame to baseplate, injecting silica gel and epoxy resin into module;
- Closing the cover lid, bending busbar terminals.



Part 1 Brief Instruction of IGBT

Product Family

- 650V-6500V full voltage rating, can meet the application for Railway, Power Grid, EV/HEV, New energy, etc.

Railway


750A Single


500A Single

6500V


2400A Single


1600A Single


800A Dual

1700V


1800A Single


1500A Single


1000A Single


500A Dual

3300V


1200A Single

4500V

Power Grid


1500A Single

3300V


3000A (PP)


1500A (PP)


1200A Single

4500V

EV/HEV


600A IPM


800A Six


600A Half


600A Six

650V/750V


600A Half


450A Half

1200V

New energy/Industry


1400A Half


1000A Half


650A Half


450A Six


300A Half


450A Half

1700V


1400A Half


900A Half


600A Half

1200V

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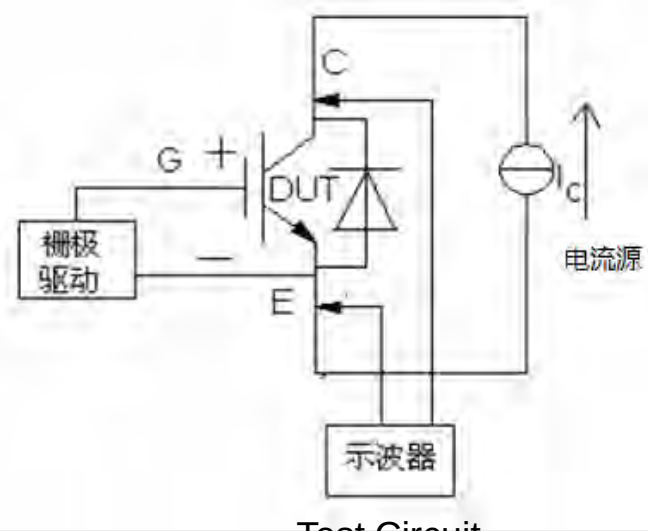
Contents

Part 2 Key Parameters of IGBT （TIM1500ESM33）

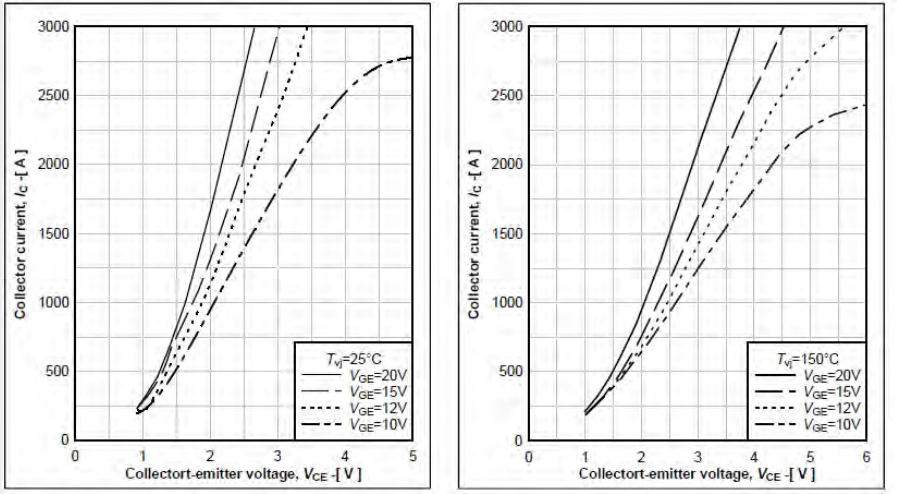
Key Static Parameters and Test Method

$V_{ce(on)}$: Collector-Emitter Saturation Voltage

- Collector-emitter voltage at specified collector-emitter current (I_C), gate threshold voltage ($V_{GE(th)}$) and T_{vj}



Test Circuit



TIM1500ESM33-PSA011

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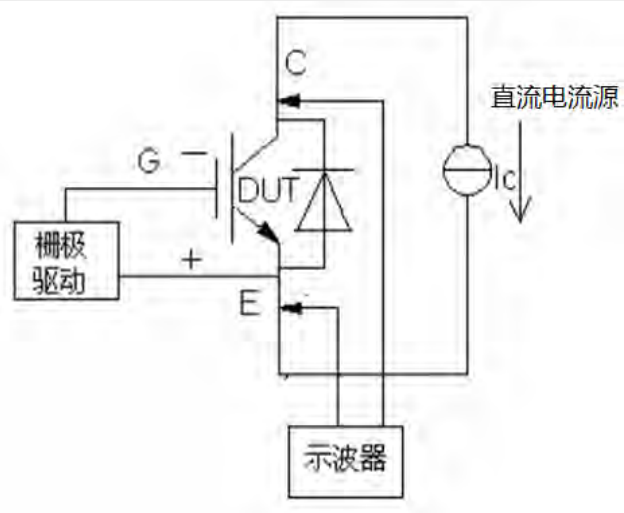
Part 2 Key Parameters of IGBT（TIM1500ESM33）

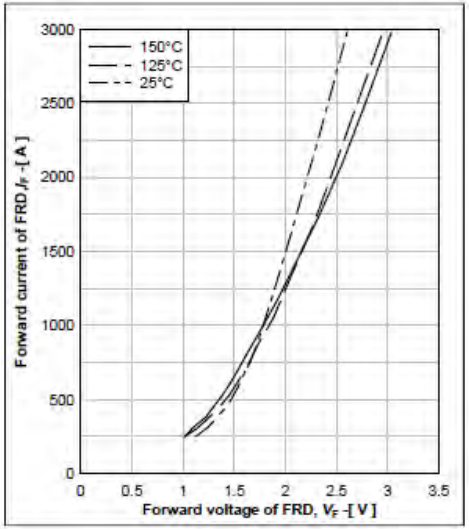
Key Static Parameters and Test Method

V_F: Diode Forward Voltage

- Forwards voltage of internal FRDs at specified diode forward current and Tvj;



Test Circuit



TIM1500ESM33-PSA011

- Negative temperature coefficient below a certain forward current.
- Positive temperature coefficient above a certain forward current.
- Positive temperature coefficient is more suitable for parallel application.

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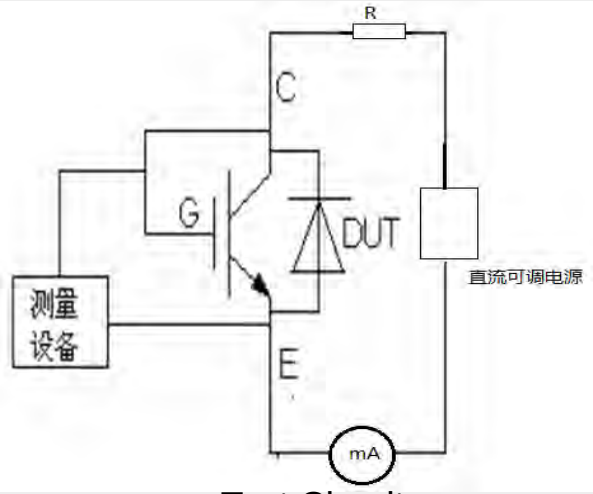
Part 2 Key Parameters of IGBT （TIM1500ESM33）

Key Static Parameters and Test Method

$V_{GE(th)}$ ： Gate Threshold Voltage

- $V_{GE(th)}$ is the gate-emitter voltage at which the collector current attains the specified value while collector and gate is short circuited.
- The smaller $V_{GE(th)}$ is, the easier it is to turn on and the faster the turn-on speed.



Test Circuit

TIM1500ESM33-PSA011

符号 (Symbol)	参数名称 (Parameter)	条件 (Test Conditions)	最小 (Min)	典型 (Typ)	最大 (Max)	单位 (Unit)
$V_{GE(TH)}$	栅极-发射极阈值电压 Gate threshold voltage	I_C = 120mA, V_{GE} = V_{CE}	5.0	5.7	6.5	V

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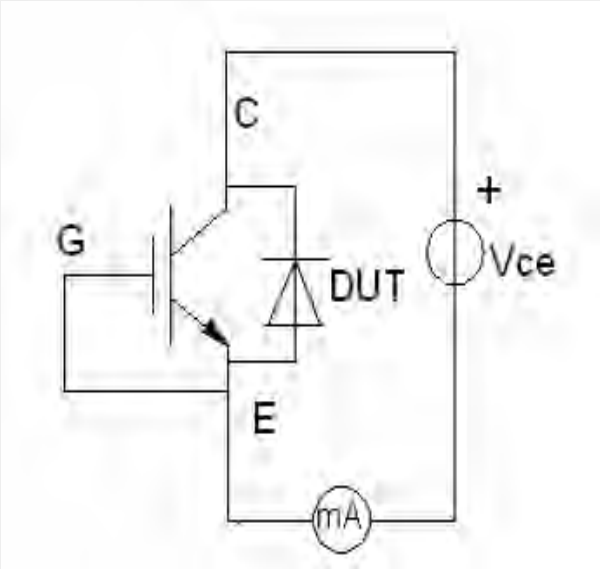
Part 2 Key Parameters of IGBT（TIM1500ESM33）

Key Static Parameters and Test Method

I_{CES}：Collector Cut-off Current

- Collector current at specified collector-emitter voltage with the gate short-circuited to the emitter.



Test Circuit

TIM1500ESM33-PSA011

符号 (Symbol)	参数名称 (Parameter)	条件 (Test Conditions)	最小 (Min)	典型 (Typ)	最大 (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_C=125 ° C			90	mA
		V_{GE} = 0V, V_{CE} = V_{CES}, T_C=150 ° C			150	mA

- FRDs are parallel connected with IGBTs, the measured I_{CES} also includes FRD' leakage current;
- G-E should be shorted during ICES testing, Otherwise, C-G junction will be charged when the collector potential is raised;
- The gate potential is also raised which causes the turn-on of IGBT module;
- Test failure, or even break the gate due to the gate voltage being too large.

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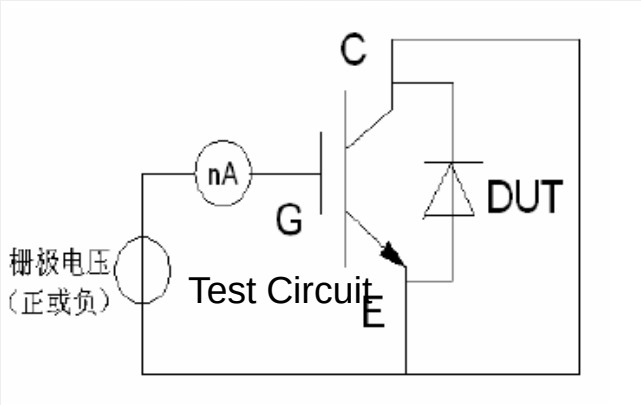
Part 2 Key Parameters of IGBT （TIM1500ESM33）

Key Static Parameters and Test Method

± I_{GES}： Gate leakage current

- **± I_{GES}** is the gate leakage current at the specified gate-emitter voltage with the collector short-circuited to the emitter.
- Maximum testing voltage no more than ± 20V. HV static electricity should be extremely avoided, accordingly, the gate and emitter conductors are usually short-circuited， during manufacture and storage.



TIM1500ESM33-PSA011

符号 (Symbol)	参数名称 (Parameter)	条件 (Test Conditions)	最小 (Min)	典型 (Typ)	最大 (Max)	单位 (Unit)
I_{GES}	栅极漏电流 Gate leakage current	V_{GE} = ±20V, V_{CE} = 0V			1	μA

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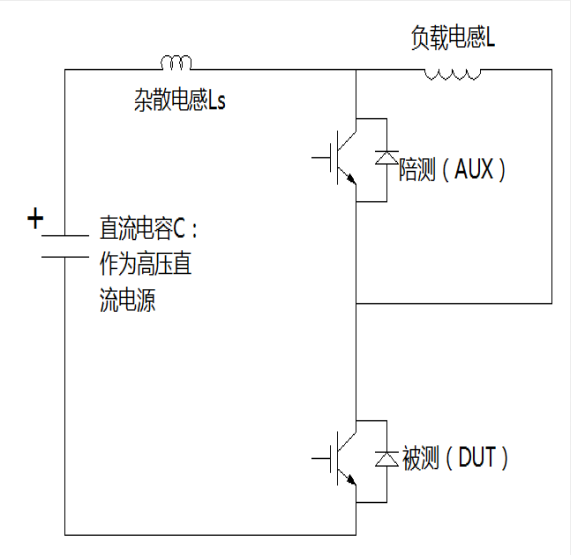
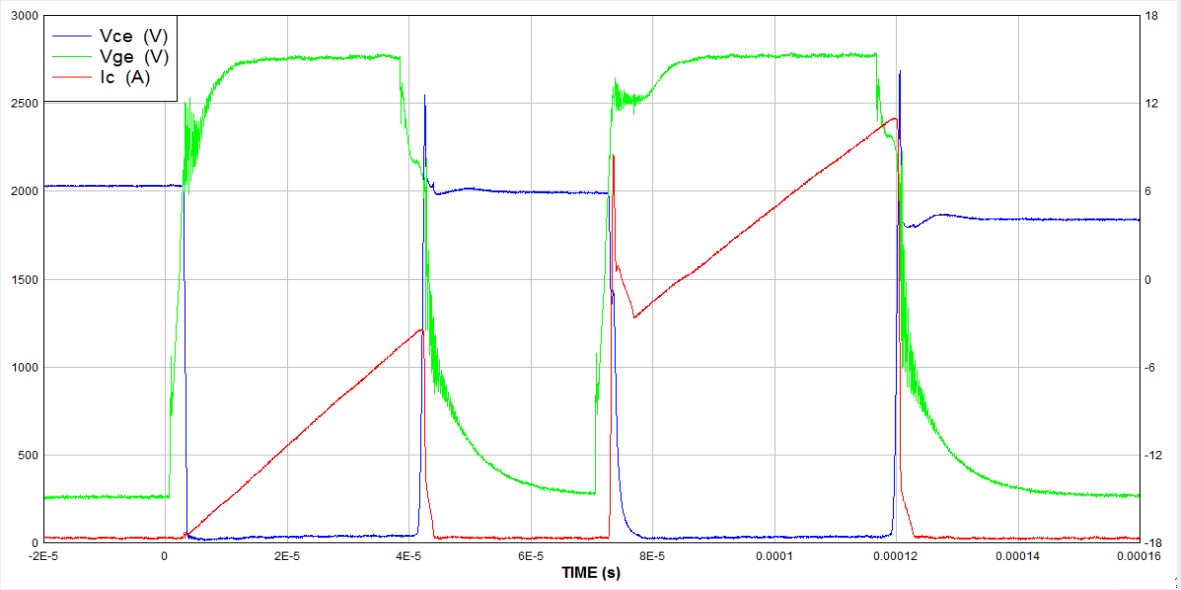
Part 2 Key Parameters of IGBT （TIM1500ESM33）

Key Static Parameters and Test Method

- Double pulse method: gate signal: DUT is double pulse (open twice), AUX is always low level (off).



Test Circuit

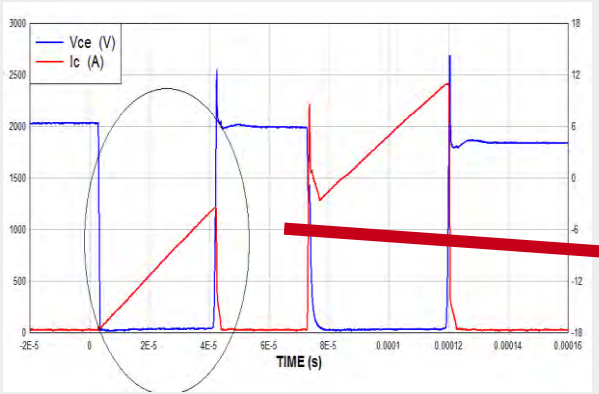


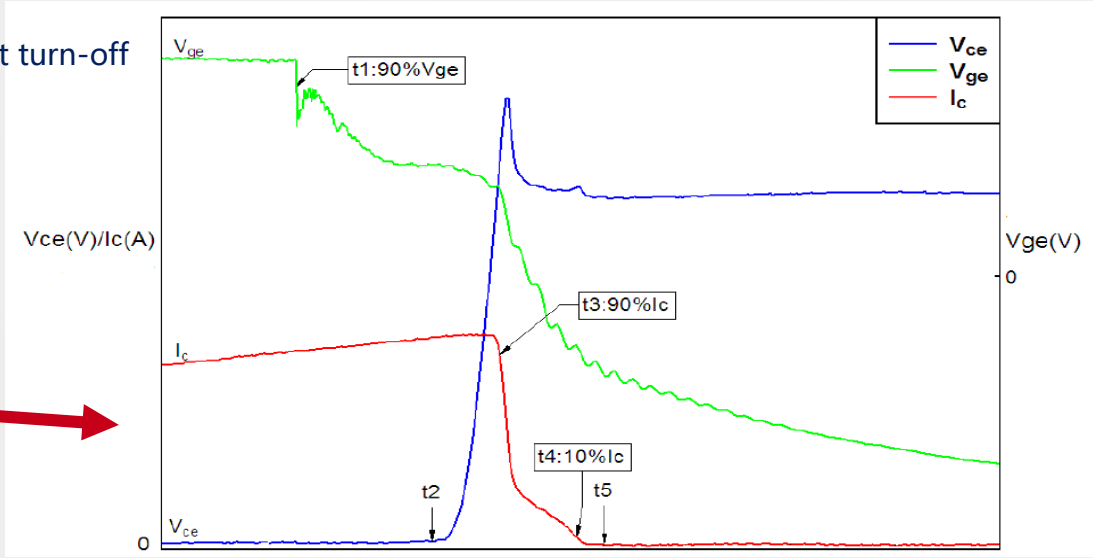
DUT Test Waveform

Part 2 Key Parameters of IGBT （TIM1500ESM33）

Key Dynamic Parameter and Test Method

- Turn-off parameter is measured via the first turn-off waveform;





- Td(off): Turn-off delay time, the time from gate voltage drop to 90% to the collector current drop to 90%;
- Tf: : Fall time, which refers to the time when the collector current drops from 90% to 10%;
- Toff: turn-off time, which is the sum of td(off) and tf;
- Eoff: Turn off switching energy. The definition is shown as formula: $E_{off} = \int_{t2}^{t5} i_c(t) \times V_{ce}(t) dt$

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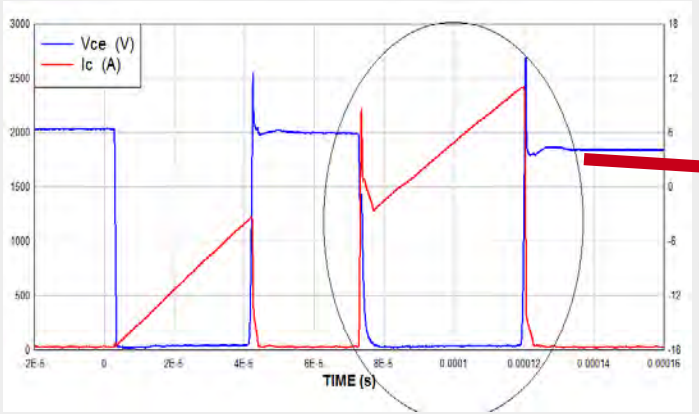
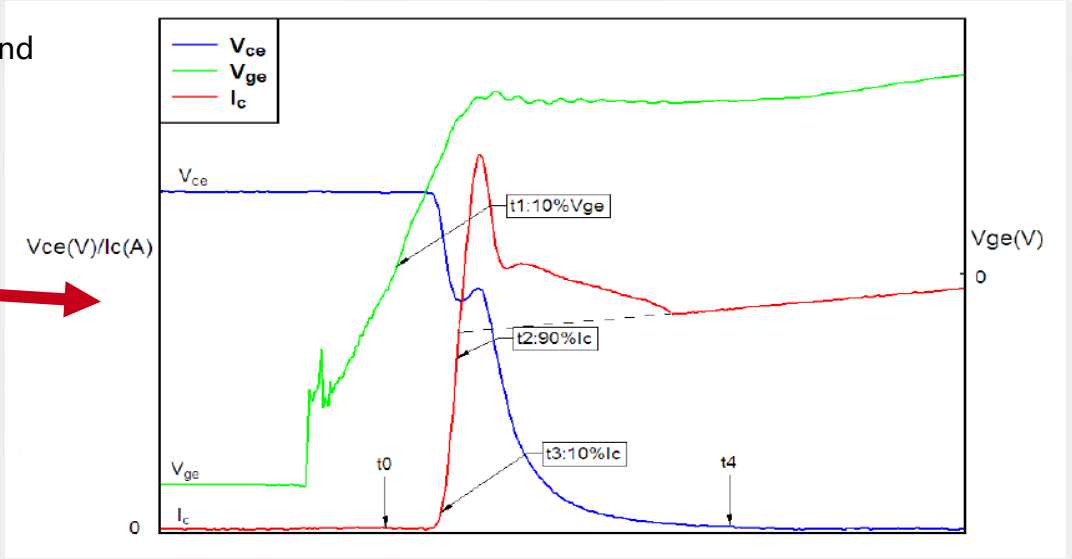
Part 2 Key Parameters of IGBT （TIM1500ESM33）

Key Dynamic Parameter and Test Method

- Turn-on parameter is measured via the second turn-on waveform;



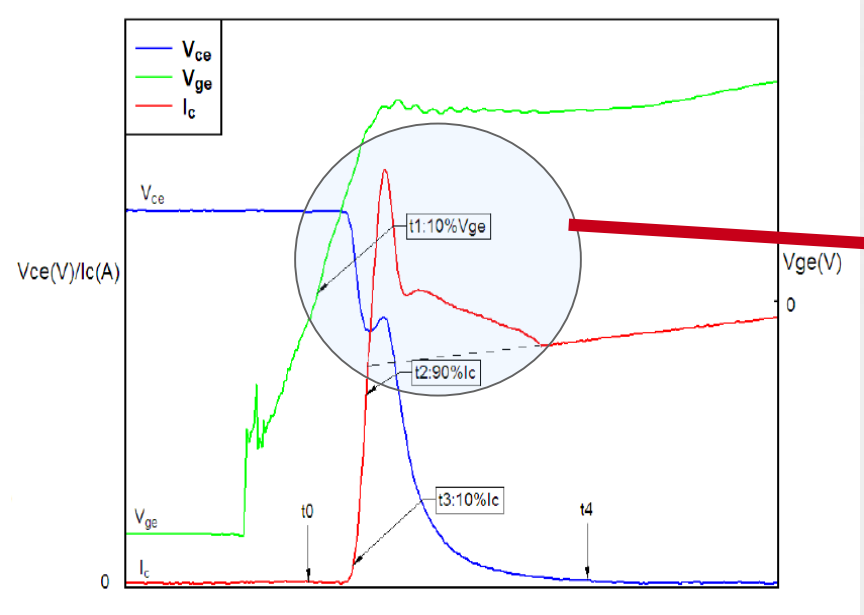


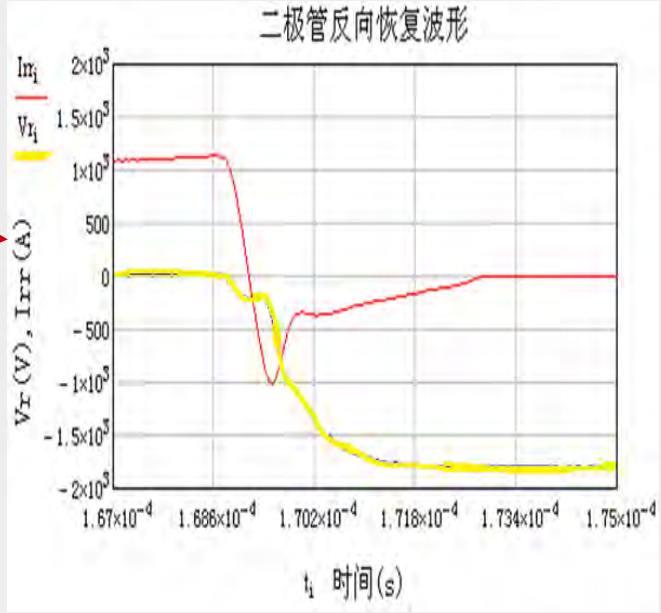
- Td(on): Turn-on delay time, the time from when the gate voltage rises to 10% to when the collector current rises to 10%;
- Tr : rise time, which refers to the time when the collector current rises from 10% to 90%;
- Ton: Turn-on time, which refers to the sum of td(on) and tr;
- Eon: Turn on switching energy. The definition is shown as formula: $E_{on} = \int_{t0}^{t4} i_c(t) \times V_{ce}(t) dt$

Part 2 Key Parameters of IGBT （TIM1500ESM33）

Key Dynamic Parameter and Test Method

- FRD reverse recovery parameters is measured via the second turn-on waveform.

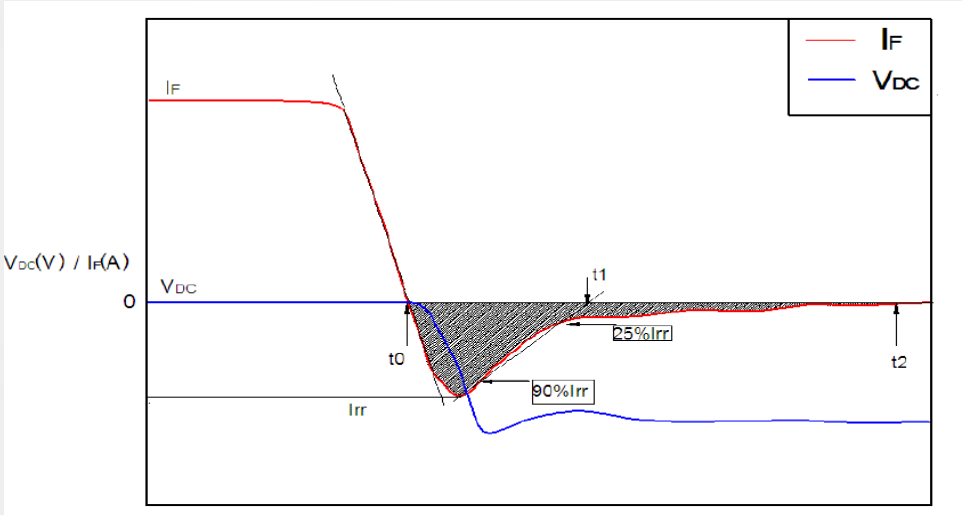




Part 2 Key Parameters of IGBT （TIM1500ESM33）

Key Dynamic Parameter and Test Method

- FRD Reverse Recovery Parameters



- Irk: Reverse recovery peak current;
- trr: Reverse recovery time, obtained by t1-t0;
- Qrr: Reverse charge recovery, obtained by integrating Irr vs time of t0~t2;
- Erec: Reverse recovery energy, The definition is shown as formula: $E_{rec} = \int_{t0}^{t2} i_c(t) \times V_{ce}(t) dt$

Contents

Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

- **Locomotive standard, much higher than industrial standard**

Type	Test Name	Referring Standard	Condition	Criteria	Status
Environment	**Passive Cycling**	EN 50439-1:2004	△Tcase=80℃ T=45℃ ~125℃ Every Cycle= 4min	20,000	Pass
	Thermal Shock	IEC 60068-2-14:1984	-40℃~+150℃ Every limited value, 2h Transfer time =30s	100cycles	Pass
	Low Temperature Storage	IEC 60068-2-1:2007	Ta=-40℃	1000hrs	Pass
	High Temperature Storage	IEC 60068-2-2:2007	Ta=150℃	1000hrs	Pass
	Salt-mist	IEC 60068-2-11:1981	35±2℃,PH=6～7 Salt/water: 5%±0.1%	168h	Pass
	Steady status damp heat	IEC 68-2-67:1995	Tvj=85℃ ,RH=85% Vce=80V ,Vge=0V	1000hrs	Pass
Mechanic	Vibration	IEC 60068-2-6:1995	F=55至500Hz G=10g	6hrs，3 Axis, 2hrs for each	Pass
	Mechanic Shock	IEC 68-2-27:1987	100g/6ms/half sine	30time，3Axis, 10time for each	Pass
Electric	HTGB)	IEC 60747-9:2007	Tvj=150℃ ,Vge=±20V	1000hrs	Pass
	HTRB	IEC 60747-9:2007	Tvj=150℃ ,Vce=0.8*Vces Vge=0V	1000hrs	Pass
	Power Cycling	IEC 60747-9:2007	△Tvj=60℃ Tvj=+65℃~+125℃ Ton=1-3s	350,000cycles	Pass

Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

- **Temperature Shock: -45℃~+125℃，every 2 limited value: 2hrs, 100 cycles**

  - Store IGBT modules in high temperature (125 ° C) and low temperature (-45 ° C) alternatively;
  - Storage time ensure junction temperature of IGBT/FRD dies to be same as ambient temperature, normally 2 hours;
  - Transferring time is no more than 1 minute, At least 100 cycles performed;
  - Pass Criteria: thermal resistance deviation doesn’ t exceed 1.2 times of original value.

Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

HTRB：1000hrs, 80%Vce，T_{vj}=150℃

- A stress accelerated test, used to identify the early defects during IGBT production process;
- The tested IGBT module is heated to the specified temperature by external heating plate;
- 80% of the rated voltage is applied between the collector and the emitter of the IGBT device
- Pass Criteria: ICES of the tested module doesn’ t exceed 1.2 times the initial value.

Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

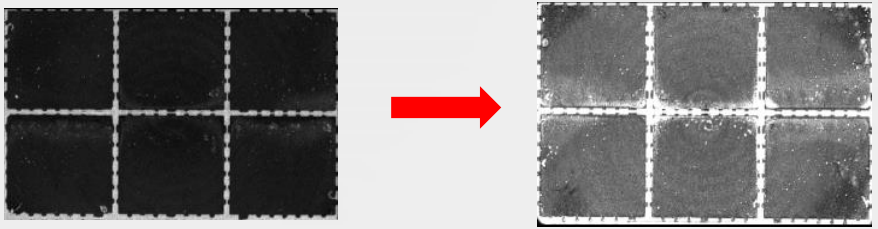
- **HTGB: 1000hrs(500hrs for negative and 500hrs for positive biased voltage), Vge= ± 20V , T_{vj}=150℃**

  - A stress acceleration test to verify the stability of IGBT gate;
  - The tested IGBT module is heated to the specified temperature by external heating plate;
  - A test-specified voltage is applied between gate and emitter of IGBT module;
  - Pass Criteria: IGES of IGBT module of the tested module doesn’ t exceed 1.2 times the initial value.

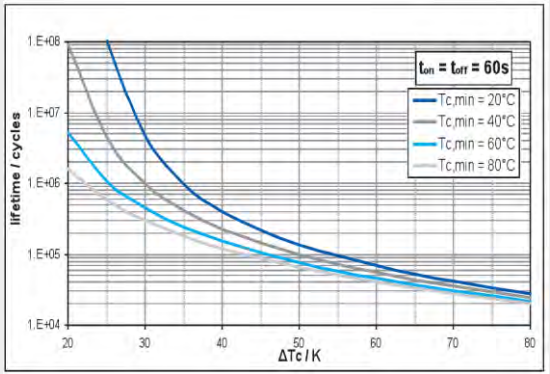
Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

Passive Thermal Cycling：Tc=45℃~125℃

- IGBT module is heated through an external heating plate, junction temperature of IGBT dies rises to a specified value;
- Turn off the heating power supply, cooling water is passed through the heating plate to cool down the junction temperature of IGBT dies to specified value;
- The cycle of each heating/cooling is generally a few minutes;
- Pass Criteria: thermal resistance change does not exceed 1.2 times the original value.



Shrinkage of soldering layer after test

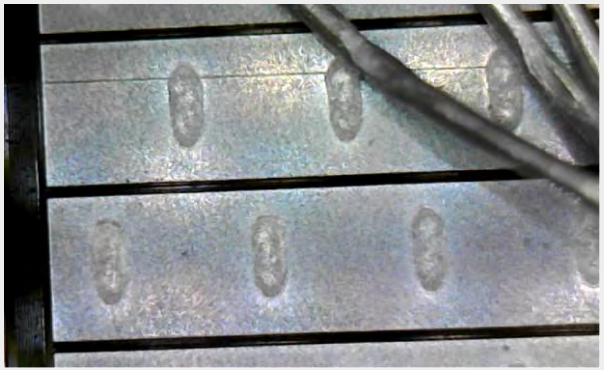


Passive Thermal Cycling Curve

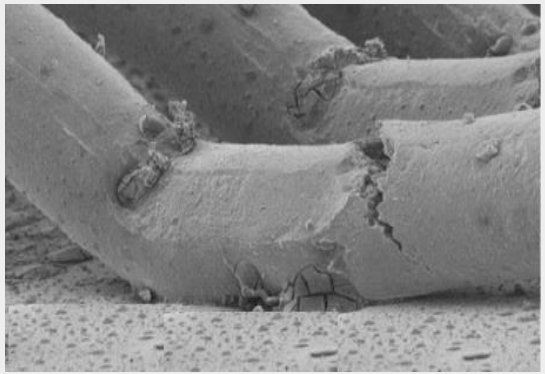
Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

Power Cycling：Tc=65℃~125℃

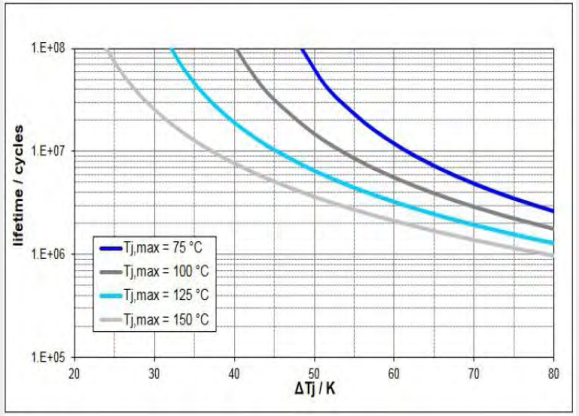
- Install the IGBT module on a water-cooled heatsink, current is applied onto IGBT modules to increase junction temperature of IGBT dies to a specified value;
- Turn off the heating power supply, cooling water is passed through the heating plate to cool down the junction temperature of IGBT dies to specified value;
- The period of each heating and cooling cycle is within in 10 seconds;
- When VCES rises to 1.2 times of the original value, the test is stopped.



Soldering Spot Stripping



Bonding Wire Cracking



Power Cycling Curve

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Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

Steady status damp heat : T_{vj}=85℃，RH=85%，Vce=80V，1000hrs

- Dies, bonding wire and solder layer are completely encapsulated by silicone material;
- Silicone material has a certain water absorption and will absorb moisture;
- Moisture will gradually affect the dies and bonding wire layer, which may cause the degradation of insulation properties or even cause failure, high humidity storage environment is a big threat to the IGBT;
- Preheating the module before starting can reduce this threat.

Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

High/Low Temperature Storage: 150 ℃/-40 ℃，1000hrs for each

- Long-term storage test under high temperature and low temperature conditions is a necessary means to verify the characteristics stability of IGBTs under specified conditions;
- Generally, the high temperature storage test time and the low temperature storage test time are both 1000 hours;
- All the parameters are tested after this test, especially the isolation capability test;
- All the parameters of module after test obtained cannot be significantly degraded from the initial value.

Low Temperature Oven

High Temperature Oven

Part 3 Part Reliability Test of IGBT （TIM1500ESM33）

- Mechanical shock: 100g/6ms/sine half-wave, 30 impacts, 10 times per axis on 3 axes, verifying the reliability of IGBT module packaging materials under transient high mechanical strength;
- Vibration: f = 55 to 500 Hz, acceleration = 10g, 6 hours, 2 hours on 3 axes, verifying the reliability of IGBT module packaging materials under continuous mechanical strength;
- Salt spray: 35 °C, 5% NaCl solution, 168 hours, verifying the reliability of the external terminals of the IGBT module to withstand environmental corrosion.

Mechanical shock Tester

Vibration Tester

Contents

Part 4 Application of IGBT

Railway

- More than 80,000pcs 3300V, 4500V, and 6500V IGBTs are widely used in railway applications. Early loading IGBTs have been running more than 1 million kilometers.
- Locomotive applications cover general electric locomotives, EMU, high-speed train
- Urban rail applications cover more than 10 metro system as well as overseas projects.

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Part 4 Application of IGBT

- As heavy-duty transportation manner, the output power of the traction converter is tremendously large with significant electromagnetic interference in the working environment, which requires the modules to have a large safe operation area (SOA);
- Long running mileage, transferred between cold zone and tropics area, which requires IGBT devices to have anti-vibration and temperature shock resistance;
- Frequent start and braking during the operation of vehicles, which requires IGBT to have strong power cycling and temperature cycling capability.

Part 4 Application of IGBT

Electric Automotive

- High power DC/DC conversion or DC/AC conversion for motor drive;
- Low power DC/AC conversion for air conditioning system;
- Switch elements in smart charging pile.

Low power passenger Car: 650V、750V IGBT

Middle power business car: 1200V IGBT

High power bus: 1700V IGBT

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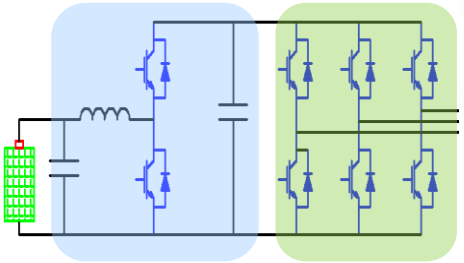
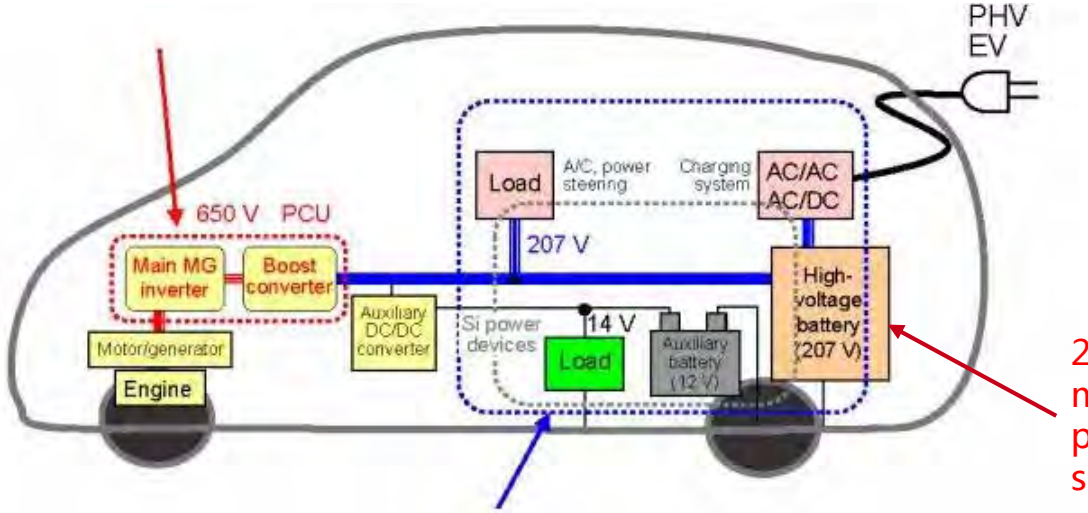
Part 4 Application of IGBT



650V Traction Unit



207V main power supply

12V auxiliary power supply

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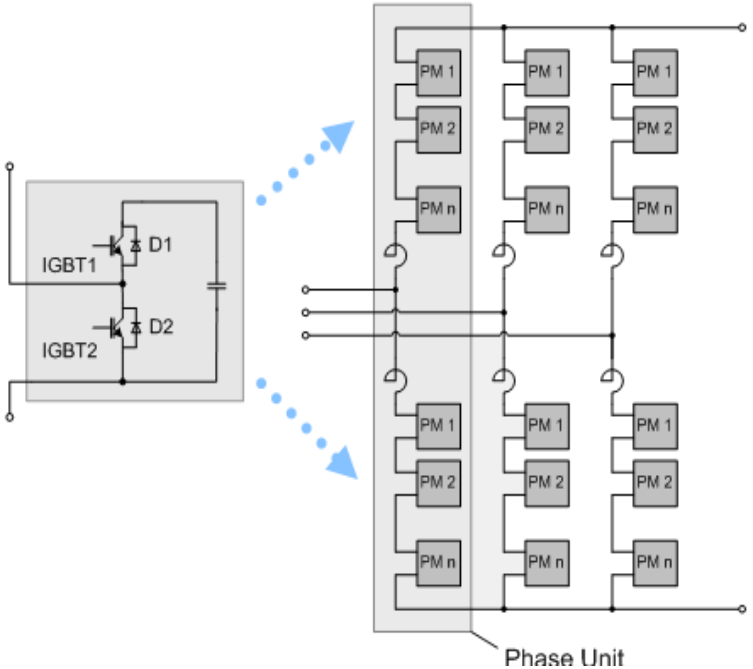
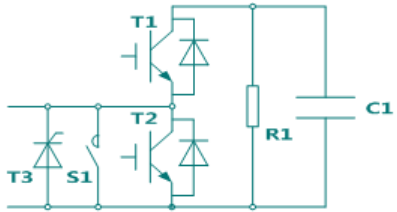
Part 4 Application of IGBT

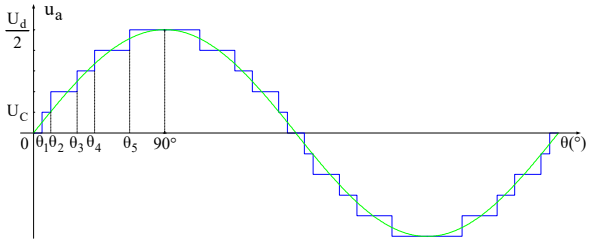
- Power Conversion

- Power generation: IGBTs are used in both rectifiers and inverters of wind power or PV;
- Power Transmission: IGBTs are widely used in light HVDC or flexible HVDC;
- Participating in the construction of flexible HVDC projects such as Xiamen, Yu'e, and Zhangbei. more than 10,000 IGBT devices with voltage ≥3300V.

Part 4 Application of IGBT







- Converter valve topology: Modular multilevel converter (MMC).

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