

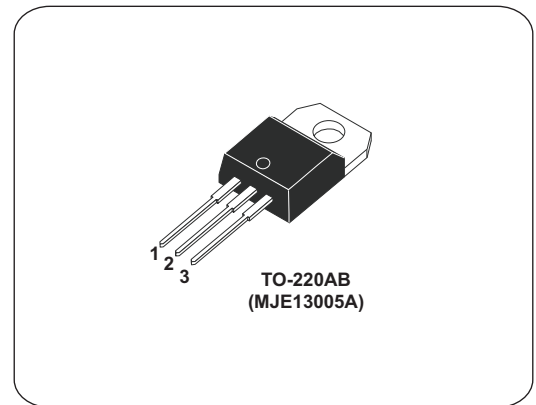
## Switchmode Series NPN Silicon Power Transistors (4A / 400V / 75W)

### FEATURES

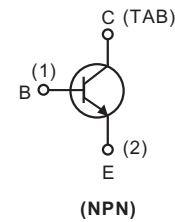
- $V_{CE(SUS)} \geq 400V @ I_C = 10 \text{ mA}, I_B = 0$
- $V_{CE(sat)} = 1.0V \text{ (Max.)} @ I_C = 4 \text{ A}, I_B = 1 \text{ A}$
- Switching time -  $t_f = 0.9 \mu\text{s} \text{ (Max.)} @ I_C = 2 \text{ A}$
- 700V blocking capability

### DESCRIPTION

These devices are designed for high-voltage, high-speed power switching inductive circuits where fall time is critical. They are particularly suited for 115 and 220V SWITCHMODE applications such as switching regulators, inverters, motor controls, solenoid/relay drivers and deflection circuits.



INTERNAL SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS ( $T_C = 25^\circ\text{C}$ unless otherwise specified)			
SYMBOL	PARAMETER		UNIT
$V_{CEV}$	Collector to base voltage ( $V_{BE} = 0$ )		V
$V_{CEO}$	Collector to emitter voltage ( $I_B = 0$ )		
$V_{EBO}$	Emitter to base voltage		
$I_C$	Collector current - continuous		A
$I_{CM}$	Peak collector current (Note 1)		
$I_B$	Base current - continuous		
$I_{BM}$	Peak base current (Note 1)		
$I_E$	Emitter current - continuous		
$I_{EM}$	Peak emitter current (Note 1)		
$P_D$	Total power dissipation	$T_C = 25^\circ\text{C}$	W
	Derate above $25^\circ\text{C}$		$\text{W}/^\circ\text{C}$
$T_j$	Junction temperature		$^\circ\text{C}$
$T_{stg}$	Storage temperature		
$T_L$	Maximum lead temperature for soldering purposes: 1/16" from case for $\leq 10$ seconds		$^\circ\text{C}$

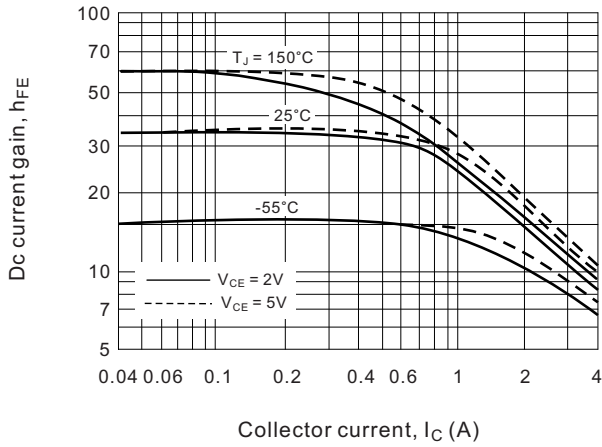
Note: 1. Pulse test : Pulse width = 5ms, duty cycle  $\leq 10\%$

THERMAL CHARACTERISTICS ( $T_C = 25^\circ\text{C}$ unless otherwise specified)			
SYMBOL	PARAMETER	VALUE	UNIT
$R_{th(j-c)}$	Maximum thermal resistance, junction to case	1.67	$^\circ\text{C/W}$
$R_{th(j-a)}$	Maximum thermal resistance, junction to ambient	62.5.	

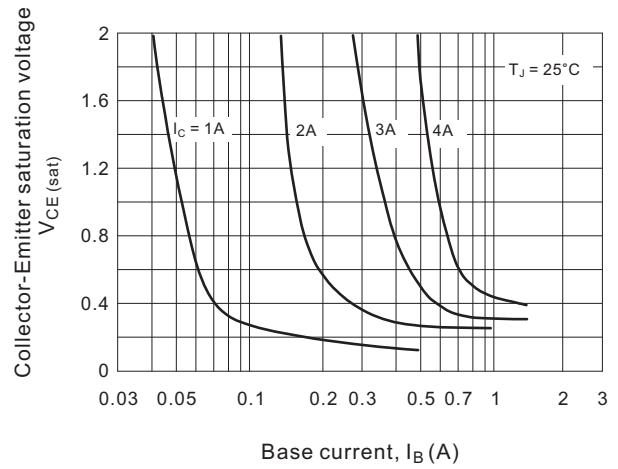
ELECTRICAL CHARACTERISTICS ( $T_C = 25^\circ\text{C}$ unless otherwise specified)						
SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFF CHARACTERISTICS</b>						
$I_{CEV}$	Collector cutoff current	$V_{CE} = 700\text{V}, V_{BE(off)} = 1.5\text{V}$			1.0	mA
		$V_{CE} = 700\text{V}, V_{BE(off)} = 1.5\text{V}, T_C = 100^\circ\text{C}$			5.0	
$I_{CEO}$	Collector cutoff current	$V_{CE} = 400\text{V}, I_B = 0$			0.1	
$I_{EBO}$	Emitter cutoff current	$V_{EBO} = 9\text{V}, I_C = 0$			1.0	
$V_{CEO(SUS)*}$	Collector to emitter sustaining voltage	$I_C = 10\text{mA}, I_B = 0$	400			V
$V_{(BR)CEV}$	Collector to base breakdown voltage	$I_C = 10\text{mA}, V_{BE} = 0$	700			
$V_{(BR)EBO}$	Emitter to base breakdown voltage	$I_E = 10\text{mA}, I_C = 0$	9			
<b>ON CHARACTERISTICS</b>						
$h_{FE}$	Forward current transfer ratio (DC current gain)	$I_C = 1\text{A}, V_{CE} = 5\text{V}$	10		60	
		$I_C = 2\text{A}, V_{CE} = 5\text{V}$	8		40	
$V_{CE(sat)*}$	Collector to emitter saturation voltage	$I_C = 1\text{A}, I_B = 0.2\text{A}$			0.5	V
		$I_C = 2\text{A}, I_B = 0.5\text{A}$			0.6	
		$I_C = 4\text{A}, I_B = 1\text{A}$			1.0	
		$I_C = 2\text{A}, I_B = 0.5\text{A}, T_C = 100^\circ\text{C}$			1.0	
$V_{BE(on)*}$	Base to emitter on voltage	$I_C = 1\text{A}, I_B = 0.2\text{A}$			1.2	V
		$I_C = 2\text{A}, I_B = 0.5\text{A}$			1.6	
		$I_C = 2\text{A}, I_B = 0.5\text{A}, T_C = 100^\circ\text{C}$			1.5	
<b>DYNAMIC CHARACTERISTICS</b>						
$f_T$	Transition frequency (Current gain- Bandwidth product)	$I_C = 0.5\text{A}, V_{CE} = 10\text{V}, f_{test} = 1\text{MHz}$	4			MHz
$C_{ob}$	Output capacitance	$V_{CB} = 10\text{V}, I_E = 0, f_{test} = 0.1\text{MHz}$		65		pF
<b>SWITCHING CHARACTERISTICS</b>						
$t_d$	Delay time	$V_{CC} = 125\text{V}, I_C = 2\text{A}$ $I_{B1} = I_{B2} = 0.4\text{A}, t_p = 25\mu\text{s}$ duty cycle $\leq 1\%$		0.03	0.1	$\mu\text{s}$
$t_r$	Rise time			0.35	0.7	
$t_s$	Storage time			2.0	4.0	
$t_f$	Fall time			0.45	0.9	

\*Pulsed : Pulse duration = 300  $\mu\text{s}$ , duty cycle = 2%.

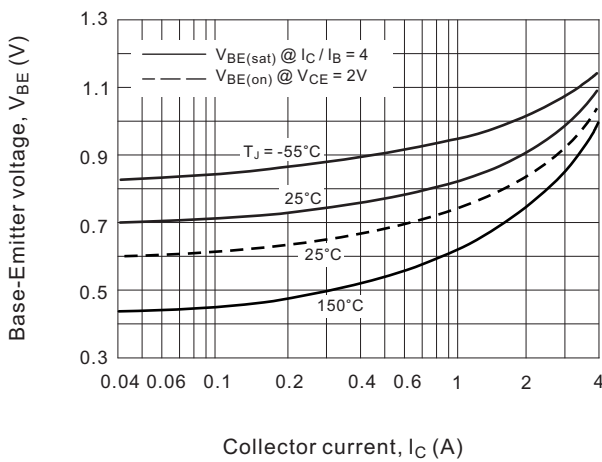
**Fig.1 DC current gain**



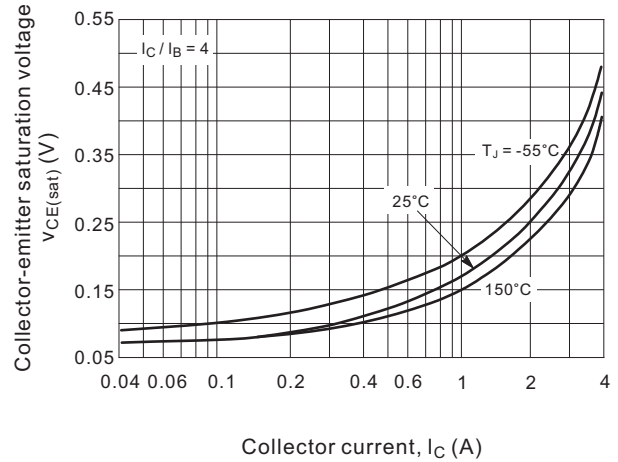
**Fig.2  $V_{CE(sat)}$  -  $I_B$  characteristics (Typical)**



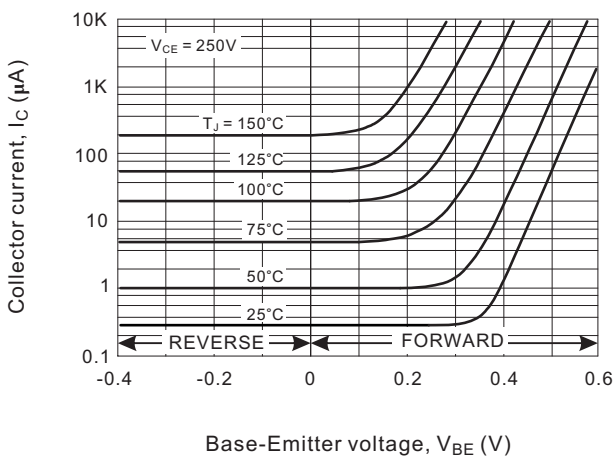
**Fig.3  $V_{BE}$  -  $I_C$  characteristics (Typical)**



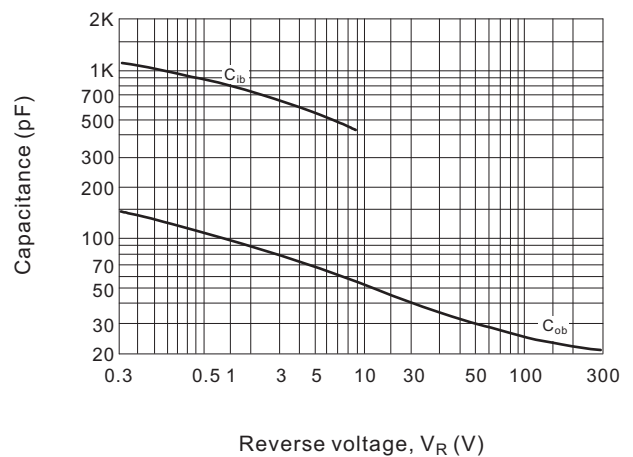
**Fig.4  $V_{CE(sat)}$  -  $I_C$  characteristics (Typical)**



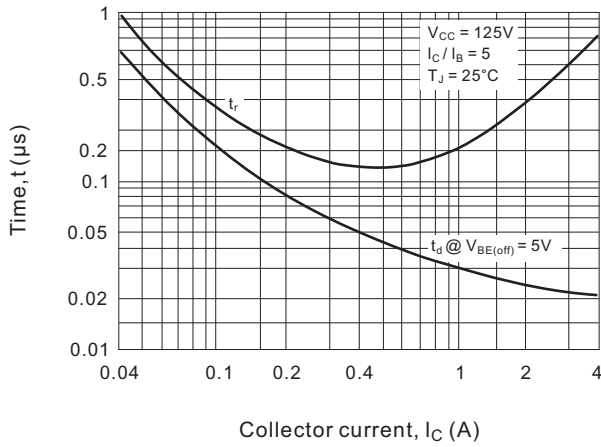
**Fig.5 Collector cutoff region**



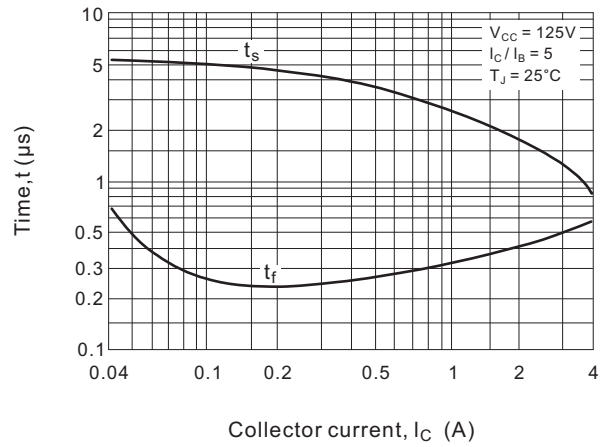
**Fig.6 Capacitance**



**Fig.7 Turn-On time**



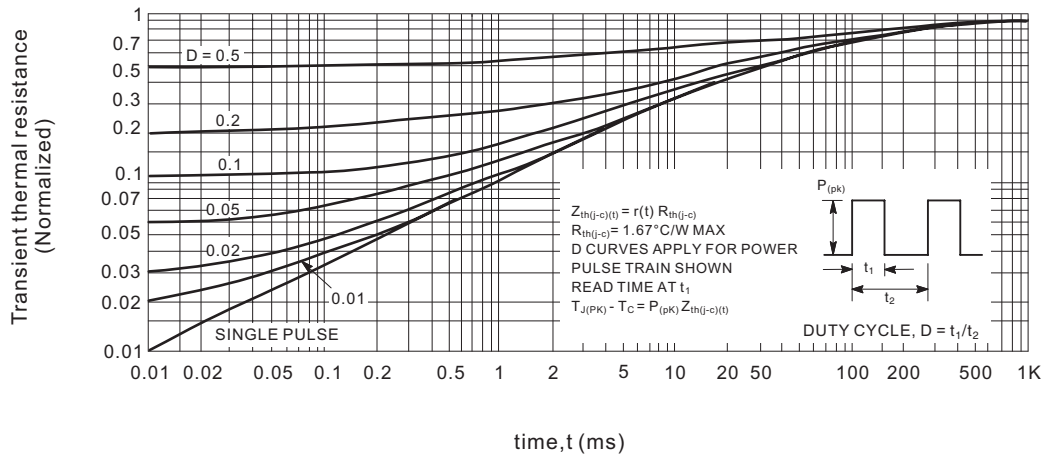
**Fig.8 Turn-Off time**



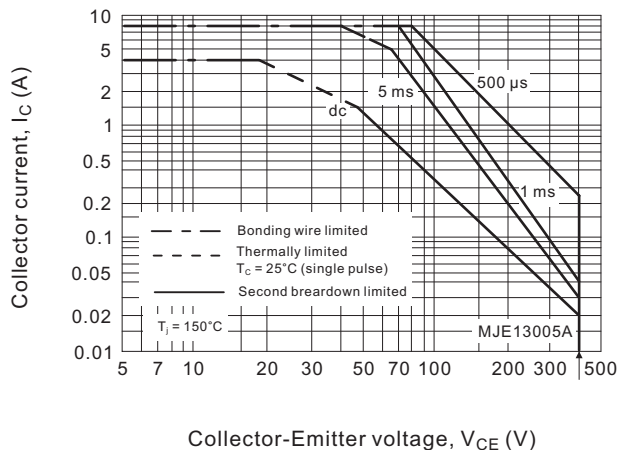
**Fig.9 Test conditions for dynamic performance**

REVERSE BIAS SAFE OPERATING AREA AND INDUCTIVE SWITCHING		RESISTIVE SWITCHING
<b>TEST CIRCUITS</b>	<p>DUTY CYCLE <math>\leq 10\%</math> <math>t_r, t_f \leq 10\text{ns}</math></p> <p><b>NOTE</b> PW and <math>V_{cc}</math> Adjusted for Desired <math>I_C</math> <math>R_B</math> Adjusted for Desired <math>I_{B1}</math></p>	
<b>CIRCUIT VALUES</b>	<p>Coil Data : Ferroxcube Core #6656 Full Bobbin (~16 Turns) #16</p> <p>GAP for 200 <math>\mu\text{H}</math> / 20A <math>L_{\text{coil}} = 200 \mu\text{H}</math></p> <p><math>V_{CC} = 20\text{V}</math> <math>V_{\text{clamp}} = 300 \text{Vdc}</math></p>	<p><math>V_{CC} = 125\text{V}</math> <math>R_C = 62\Omega</math> <math>D1 = 1\text{N}5820</math> or Equiv. <math>R_B = 22\Omega</math></p>
<b>TEST WAVEFORMS</b>	<p>Test Equipment Scope-Tektronics 475 or Equivalent</p>	<p><math>t_r, t_f &lt; 10\text{ns}</math> Duty Cycle = 1.0% <math>R_B</math> and <math>R_C</math> adjusted for desired <math>I_B</math> and <math>I_C</math></p>

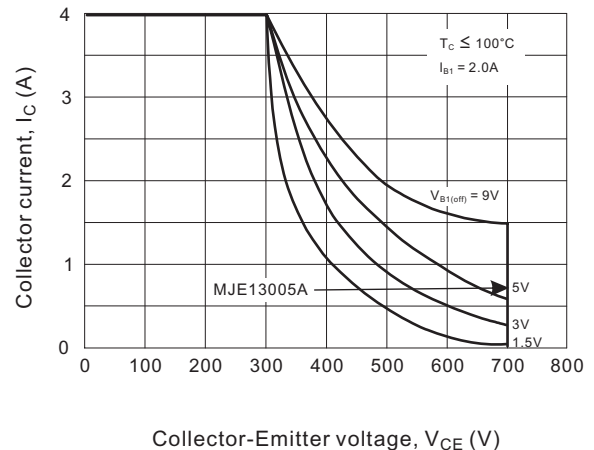
**Fig.10 Typical thermal response [ $Z_{th(j-c)}(t)$ ]**



**Fig.11 Forward bias safe operating area (FBSOA)**



**Fig.12 Reverse bias switching safe operating area (RBSOA)**



### FORWARD BIAS

There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate  $I_C - V_{CE}$  limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

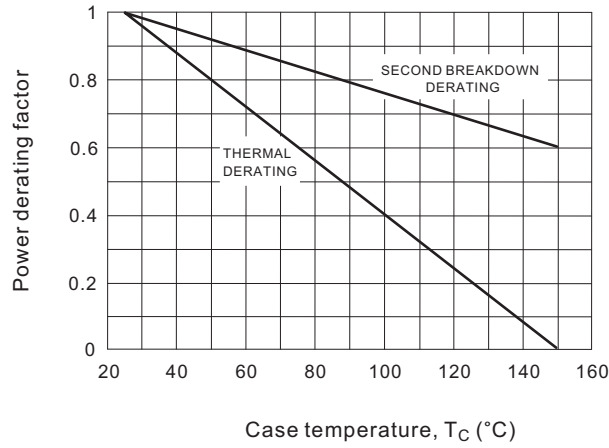
The data of Fig.11 is based on  $T_C = 25^\circ\text{C}$ ;  $T_{J(pk)}$  is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when  $T_C \geq 25^\circ\text{C}$ . Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Fig.11 may be found at any case temperature by using the appropriate curve on Fig.13.

$T_{J(pk)}$  may be calculated from the data in Fig.10. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

### REVERSE BLAS

For inductive loads, high voltage and high current must be sustained simultaneously during turn-off, in most cases, with the base to emitter junction reverse biased. Under these conditions the collector voltage must be held to a safe level at or below a specific value of collector current. This can be accomplished by several means such as active clamping, RC snubbing, load line shaping, etc. The safe level for these devices is specified as Reverse Bias Safe Operating Area and represents the voltage-current conditions during reverse biased turn-off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Fig.12 gives the complete RBSOA characteristics.

**Fig.13 Forward bias power derating**



**TO-220AB**

