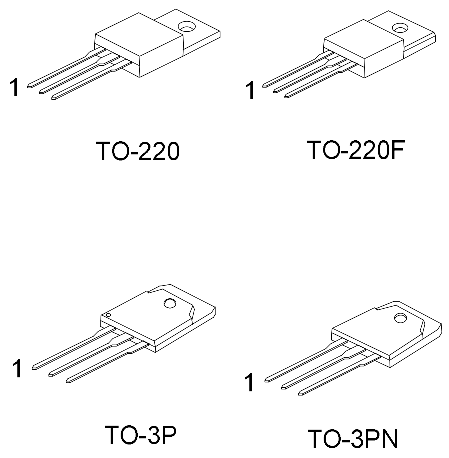
SWITCHMODE SERIES NPN SILICON POWER TRANSISTORS



■ DESCRIPTION

The **MJE13009** is designed for high-voltage, high-speed power switching inductive circuits where fall time is critical. They are particularly suited for 115 and 220V switch mode applications such as Switching Regulators, Inverters, Motor Controls, Solenoid/Relay drivers and Deflection circuits.

■ FEATURES

* V_{CEO} 400V and 300V
* Reverse Bias SOA with Inductive Loads @ T_C = 100°C
* Inductive Switching Matrix 3 ~ 12 Amp, 25 and 100°C
  t_C @ 8A, 100°C is 120 ns (Typ.).
* 700 V Blocking Capability
* SOA and Switching Applications Information.

■ ORDERING INFORMATION

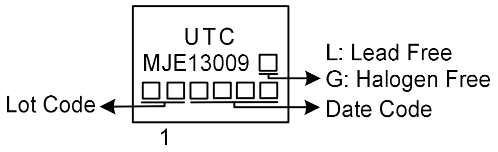
Ordering Number		Package	Pin Assignment			Packing
Lead Free	Halogen Free		1	2	3	
MJE13009L-TA3-T	MJE13009G-TA3-T	TO-220	B	C	E	Tube
MJE13009L-TF3-T	MJE13009G-TF3-T	TO-220F	B	C	E	Tube
MJE13009L-T3P-T	MJE13009G-T3P-T	TO-3P	B	C	E	Tube
MJE13009L-T3N-T	MJE13009G-T3N-T	TO-3PN	B	C	E	Tube

Note: Pin Assignment: B: Base C: Collector E: Emitter

MJE13009G-TA3-T
(1)Packing Type
(2)Package Type
(3)Green Package

(1) T: Tube
(2) TA3: TO-220, TF3: TO-220F, T3P: TO-3P
T3N: TO-3PN
(3) G: Halogen Free and Lead Free, L: Lead Free

■ MARKING



■ ABSOLUTE MAXIMUM RATINGS (T_A=25°C, unless otherwise specified)

PARAMETER		SYMBOL	RATINGS	UNIT
Collector-Emitter Voltage		V_{CEO}	400	V
Collector-Emitter Voltage (V_{BE}=-1.5V)		V_{CEV}	700	V
Emitter Base Voltage		V_{EBO}	9	V
Collector Current	Continuous	I_C	12	A
	Peak (Note 3)	I_{CM}	24	A
Base Current	Continuous	I_B	6	A
	Peak (Note 3)	I_{BM}	12	A
Emitter Current	Continuous	I_E	18	A
	Peak (Note 3)	I_{EM}	36	A
Power Dissipation	TO-220	P_D	2	W
	TO-220F		2	W
	TO-3P		5.8	W
Derate above 25°C	TO-220/TO-220F		16	mW/°C
	TO-3P		47	mW/°C
Junction Temperature		T_J	+150	°C
Storage Temperature		T_{STG}	-40 ~ +150	°C

Notes: 1. Absolute maximum ratings are those values beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.
2. Pulse Test: Pulse Width = 5ms, Duty Cycle ≤ 10%.
3. Pulse Test: Pulse Width = 300μs, Duty Cycle = 2%.

■ THERMAL DATA

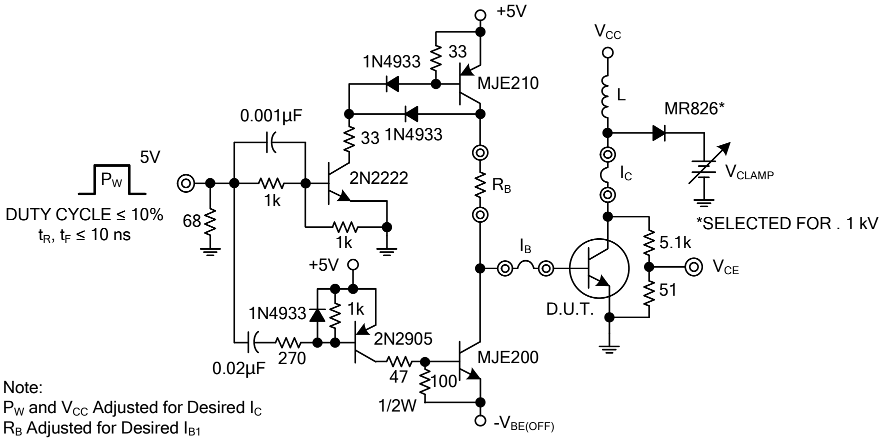
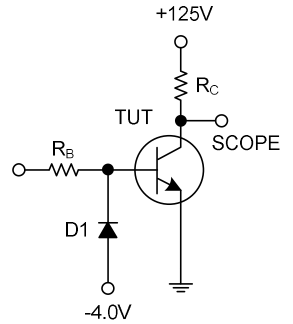
PARAMETER		SYMBOL	RATINGS	UNIT
Junction to Ambient	TO-220/TO-220F	θ_{JA}	62.5	°C/W
	TO-3P		21	°C/W
Junction to Case	TO-220	θ_{JC}	1.56	°C/W
	TO-220F		3.13	°C/W
	TO-3P		0.6	°C/W

■ ELECTRICAL CHARACTERISTICS (T_C=25°C, unless otherwise specified)

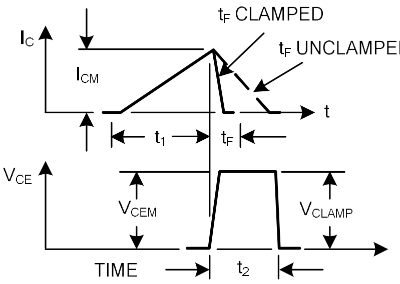
PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFF CHARACTERISTICS (Note)						
Collector- Emitter Sustaining Voltage	V_{CEO}	I_C = 10mA, I_B = 0	400			V
Collector Cutoff Current V_{CBO}=Rated Value	I_{CEV}	$V_{BE(OFF)}$ = 1.5V_{DC}			1	mA
		$V_{BE(OFF)}$ = 1.5V_{DC}, T_C = 100°C			5	mA
Emitter Cutoff Current	I_{EBO}	V_{EB} = 9V_{DC}, I_C = 0			1	mA
ON CHARACTERISTICS (Note)						
DC Current Gain	h_{FE1}	I_C = 5A, V_{CE} = 5V			40	
	h_{FE2}	I_C = 8A, V_{CE} = 5V			30	
Current-Emitter Saturation Voltage	$V_{CE(SAT)}$	I_C = 5A, I_B = 1A			1	V
		I_C = 8A, I_B = 1.6A			1.5	V
		I_C = 12A, I_B = 3A			3	V
		I_C = 8A, I_B = 1.6A, T_C = 100°C			2	V
Base-Emitter Saturation Voltage	$V_{BE(SAT)}$	I_C = 5A, I_B = 1A			1.2	V
		I_C = 8A, I_B = 1.6A			1.6	V
		I_C = 8A, I_B = 1.6A, T_C = 100°C			1.5	V
DYNAMIC CHARACTERISTICS						
Transition frequency	f_T	I_C = 500mA, V_{CE} = 10V, f = 1MHz	4			MHz
Output Capacitance	C_{OB}	V_{CB} = 10V, I_E = 0, f = 0.1MHz		180		pF
SWITCHING CHARACTERISTICS (Resistive Load, Table 1)						
Delay Time	t_{DLY}	V_{CC} = 125Vdc, I_C = 8A, I_{B1} = I_{B2} = 1.6A, t_P = 25μs, Duty Cycle ≤1%		0.06	0.1	μs
Rise Time	t_R			0.45	1	μs
Storage Time	t_S			1.3	3	μs
Fall Time	t_F			0.2	0.7	μs
Inductive Load, Clamped (Table 1, Fig. 13)						
Voltage Storage Time	t_S	I_C=8A, V_{CLAMP}=300V, I_{B1}=1.6A, $V_{BE(OFF)}$ = 5V, T_C = 100°C		0.92	2.3	μs
Crossover Time	t_C			0.12	0.7	μs

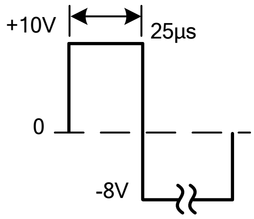
Note: Pulse Test: Pulse Wieth = 300μs, Duty Cycle = 2%.

■ TABLE 1. TEST CONDITIONS FOR DYNAMIC PERFORMANCE

<table>
<tr><th></th><th>REVERSE BIAS SAFE OPERATING AREA AND INDUCTIVE SWITCHING</th><th>RESISTIVE SWITCHING</th></tr>
<tr><td>TEST CIRCUITS</td><td>
</td><td>
</td></tr>
<tr><td>CIRCUIT VALUES</td><td>Coil Data:
Ferroxcube Core #6656
Full Bobbin (~16 Turns) #16

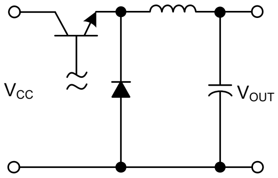
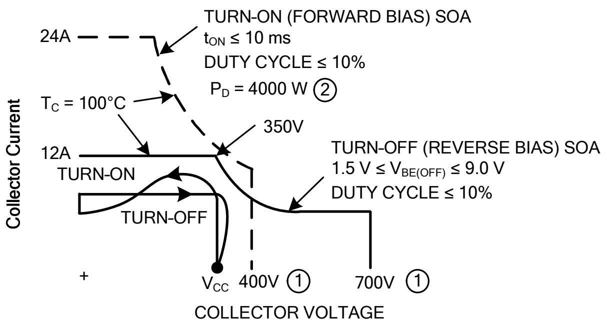
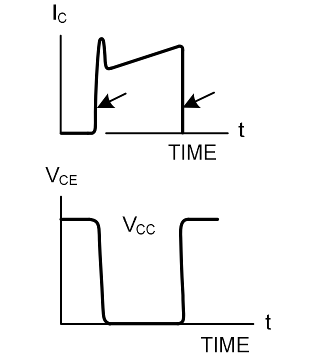
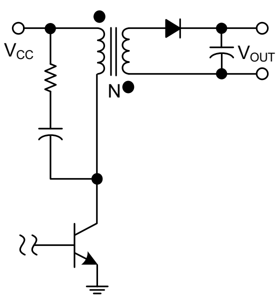
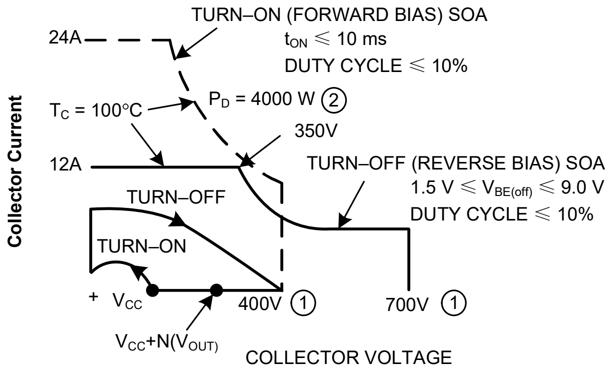
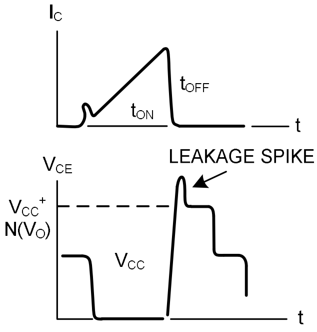
GAP for 200μH/20A
L_{COIL} = 200μH

V_{CC} = 20V
V_{CLAMP} = 300V_{DC}</td><td>V_{CC} = 125V
R_C = 15Ω
D1 = 1N5820 or Equiv.
R_B = Ω</td></tr>
<tr><td>TEST WAVEFORMS</td><td>OUTPUT WAVEFORMS


t1 ADJUSTED TO OBTAIN IC
$t_1 \approx \frac{L_{COIL}(I_{CM})}{V_{CC}}$
$t_2 \approx \frac{L_{COIL}(I_{CM})}{V_{CLAMP}}$
Test Equipment
Scope-Tektronics
475 or Equivalent</td><td>

t_R, t_F < 10 ns
Duty Cycle = 1.0%
R_B and R_C adjusted for desired I_B and I_C</td></tr>
</table>

■ TABLE 2. APPLICATIONS EXAMPLES OF SWITCHING CIRCUITS

<table>
<tr><th>CIRCUIT</th><th>LOAD LINE DIAGRAMS</th><th>TIME DIAGRAMS</th></tr>
<tr><td>SERIES SWITCHING REGULATOR

</td><td>
</td><td>
</td></tr>
<tr><td>RINGING CHOKE INVERTER

</td><td>
</td><td>
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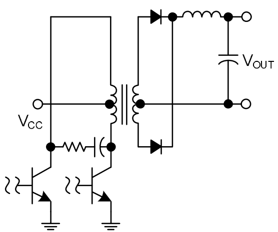
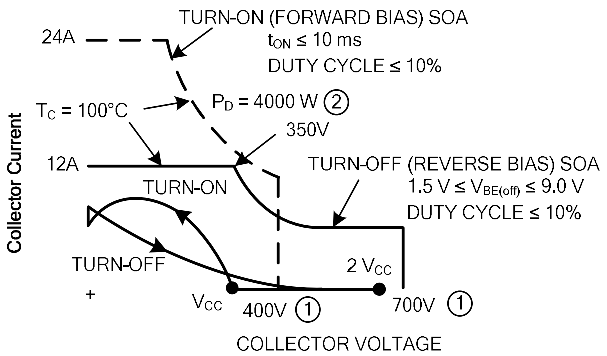
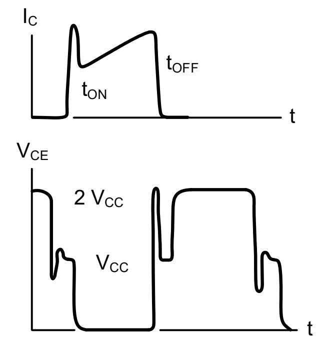
<tr><td>PUSH–PULL INVERTER/CONVERTER

</td><td>
</td><td>
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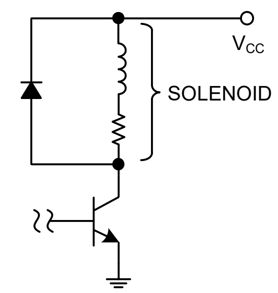
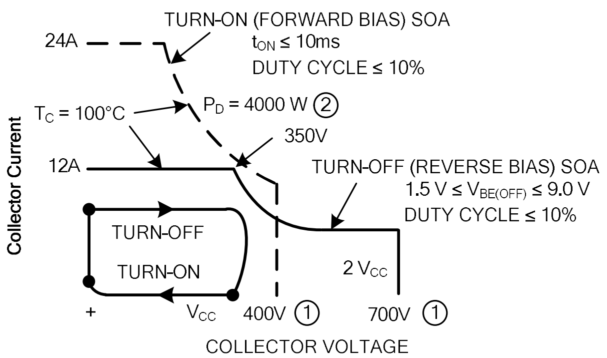
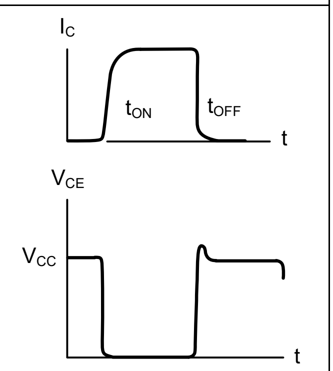
<tr><td>SOLENOID DRIVER

</td><td>
</td><td>
</td></tr>
</table>

■ TABLE 3. TYPICAL INDUCTIVE SWITCHING PERFORMANCE

I_C(A)	T_C(℃)	t_{SV}(ns)	t_{RV}(ns)	t_{FI}(ns)	t_{TI}(ns)	t_C(ns)
3	25 100	770 1000	100 230	150 160	200 200	240 320
5	25 100	630 820	72 100	26 55	10 30	100 180
8	25 100	720 920	55 70	27 50	2 8	77 120
12	25 100	640 800	20 32	17 24	2 4	41 54

■ SWITCHING TIME NOTES

In resistive switching circuits, rise, fall, and storage times have been defined and apply to both current and voltage waveforms since they are in phase. However, for inductive loads which are common to SWITCHMODE power supplies and hammer drivers, current and voltage waveforms are not in phase. Therefore, separate measurements must be made on each waveform to determine the total switching time. For this reason, the following new terms have been defined.

t_{SV} = Voltage Storage Time, 90% I_{B1} to 10% V_{CEM}
t_{RV} = Voltage Rise Time, 10–90% V_{CEM}
t_{FI} = Current Fall Time, 90–10% I_{CM}
t_{TI} = Current Tail, 10–2% I_{CM}
t_C = Crossover Time, 10% V_{CEM} to 10% I_{CM}

An enlarged portion of the turn–off waveforms is shown in Fig. 13 to aid in the visual identity of these terms.

For the designer, there is minimal switching loss during storage time and the predominant switching power losses occur during the crossover interval and can be obtained using the standard equation from AN–222:

$P_{SWT} = 1/2\ V_{CC} I_C (t_C)\ f$

Typical inductive switching waveforms are shown in Fig. 14. In general, $t_{RV} + t_{FI} \approx t_C$. However, at lower test currents this relationship may not be valid.

As is common with most switching transistors, resistive switching is specified at 25℃ and has become a benchmark for designers. However, for designers of high frequency converter circuits, the user oriented specifications which make this a “SWITCHMODE” transistor are the inductive switching speeds (t_C and t_{SV}) which are guaranteed at 100℃.

■ TYPICAL CHARATERISTICS

Fig. 1 Forward Bias Safe Operating Area

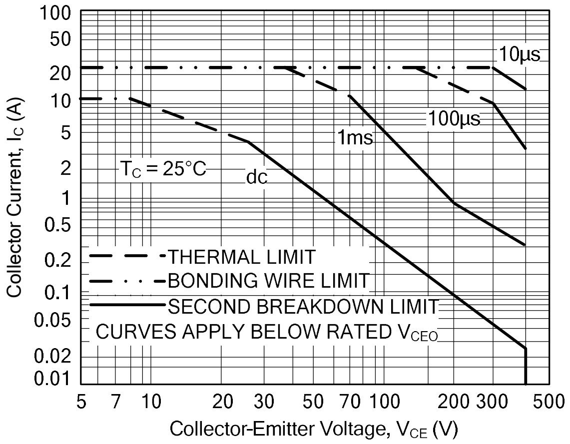


Fig. 2 Reverse Bias Switching Safe Operating Area

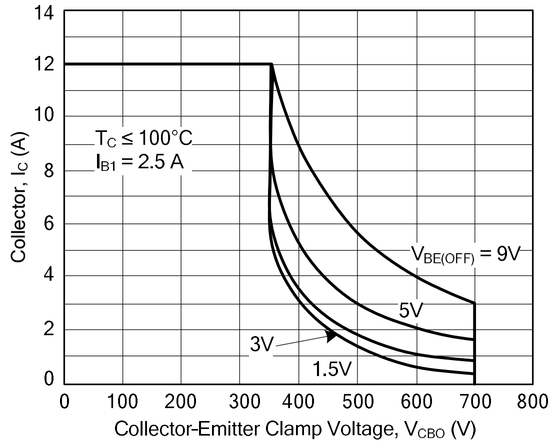
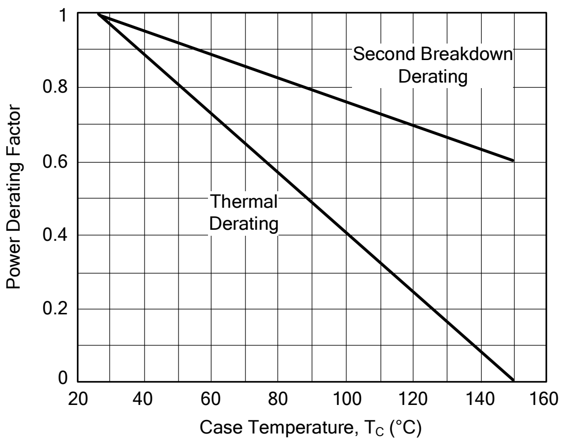


Fig. 3 Forward Bias Power Derating

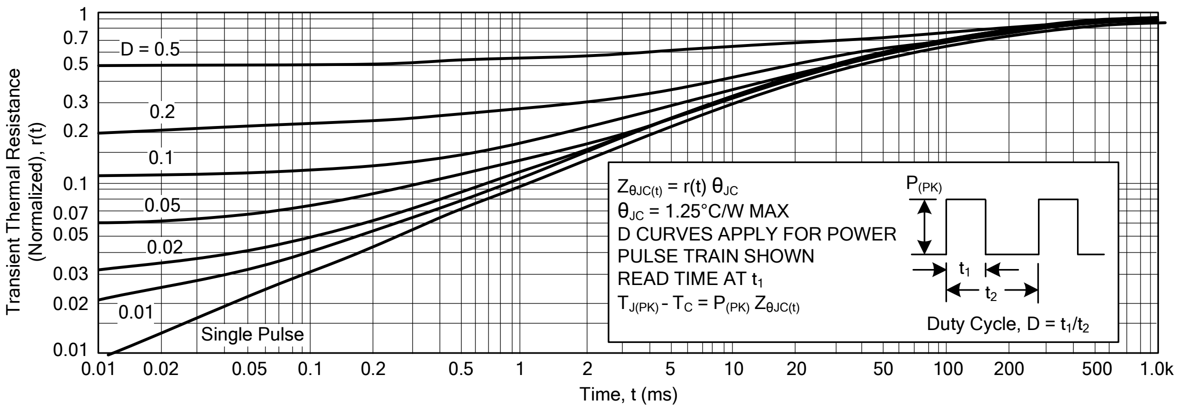


There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate I_C - V_{CE} limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation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

The data of Fig. 1 is based on T_C=25°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 $T_C \geq 25°C$. Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Fig. 1 may be found at any case temperature by using the appropriate curve on Fig. 3.

$T_{J(PK)}$ may be calculated from the data in Fig. 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. Use of reverse biased safe operating area data (Fig. 2) is discussed in the applications information section.

Fig. 4 Typical Thermal Response [$Z_{\theta JC}(t)$]



■ TYPICAL CHARACTERISTICS (Cont.)

Fig. 5 DC Current Gain

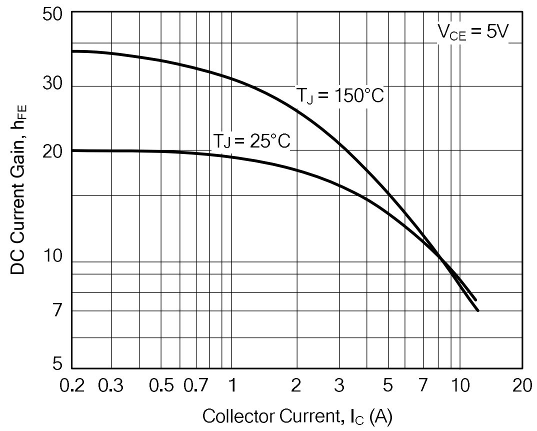


Fig. 6 Collector Saturation Region

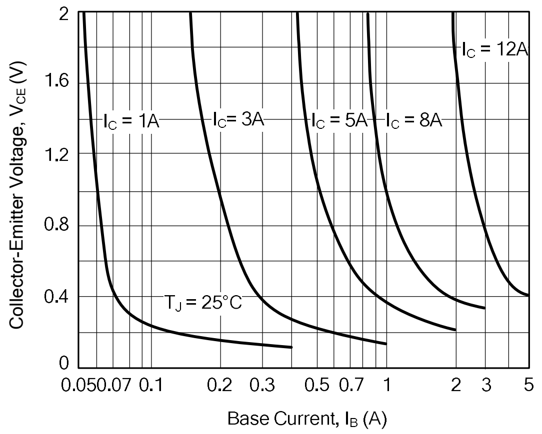


Fig. 7 Base-Emitter Saturation Voltage

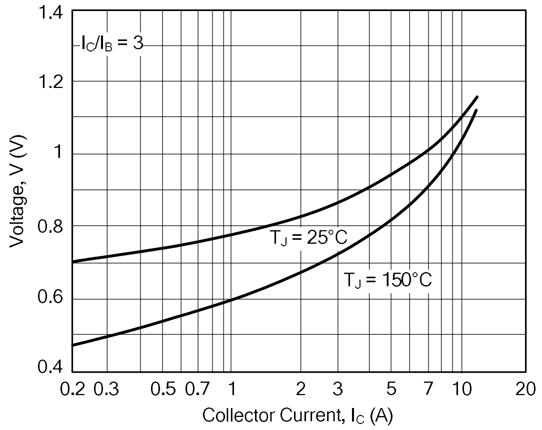


Fig. 8 Collector-Emitter Saturation Voltage

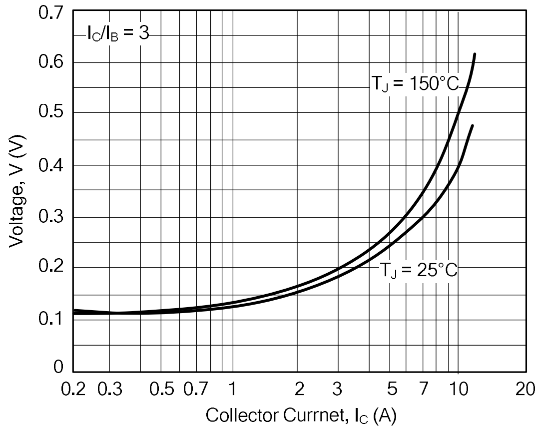


Fig. 9 Collector Cutoff Region

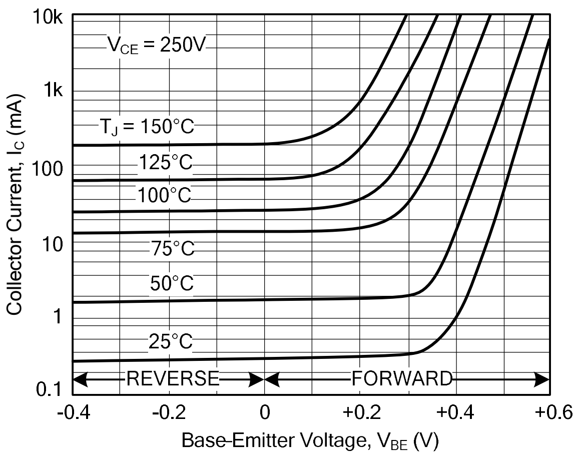
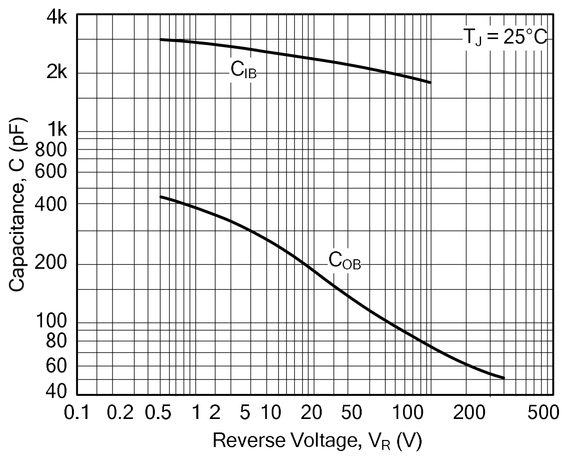


Fig. 10 Capacitance



■ RESISTIVE SWITCHING PERFORMANCE

Fig. 11. Turn-On Time

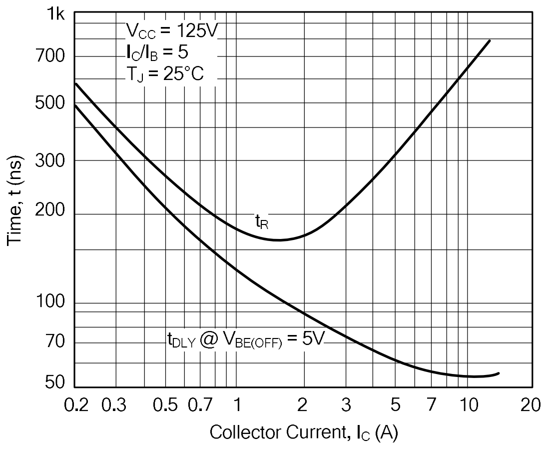


Fig. 12 Turn-Off Time

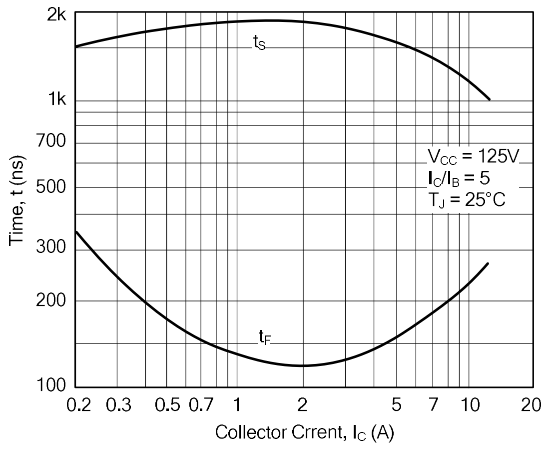


Fig. 13 Typical Inductive Switching Waveforms
(at 300V and 12A with I_{B1} = 2.4A and $V_{BE(off)}$ = 5V)