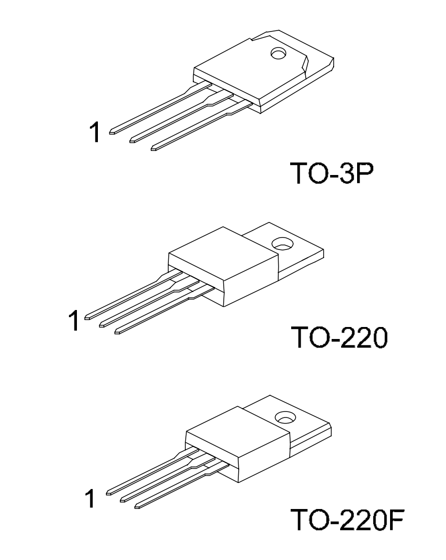
MJE13009

NPN SILICON TRANSISTOR

SWITCHMODE SERIES NPN SILICON POWER TRANSISTORS



*Pb-free plating product number:MJE13009L

■ 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 220 V switch mode applications such as Switching Regulators, Inverters, Motor Controls, Solenoid/Relay drivers and Deflection circuits.

■ FEATURES

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

■ ORDERING INFORMATION

Order Number		Package	Pin Assignment			Packing
Normal	Lead Free Plating		1	2	3	
MJE13009-TA3-T	MJE13009L-TA3-T	TO-220	B	C	E	Tube
MJE13009-TF3-T	MJE13009L-TF3-T	TO-220F	B	C	E	Tube
MJE13009-T3P-T	MJE13009L-T3P-T	TO-3P	B	C	E	Tube

MJE13009L-TA3-T	
(1)Packing Type	(1) T: Tube
(2)Package Type	(2) TA3: TO-220, TF3: TO-220F, T3P: TO-3P
(3)Lead Plating	(3) L: Lead Free Plating, Blank: Pb/Sn

■ ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

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*	I_{CM}	24	
Base Current	Continuous	I_B	6	A
	Peak*	I_{BM}	12	
Emitter Current	Continuous	I_E	18	A
	Peak*	I_{EM}	36	
Total Power Dissipation @ Ta = 25°C		P_D	2	W
Derate above 25°C			16	mW/°C
Total Power Dissipation @ T_C = 25°C		P_D	100	W
Derate above 25°C			800	mW/°C
Junction Temperature		T_J	+150	°C
Storage Temperature		T_{STG}	-40 ~ +150	°C

Note: 1. Pulse Test: Pulse Width = 5ms, Duty Cycle ≤ 10%
2. 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.

■ THERMAL DATA

PARAMETER	SYMBOL	RATINGS	UNIT
Thermal Resistance Junction to Ambient	θ_{JA}	54	°C/W
Thermal Resistance Junction to Case	θ_{JC}	4	°C/W

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

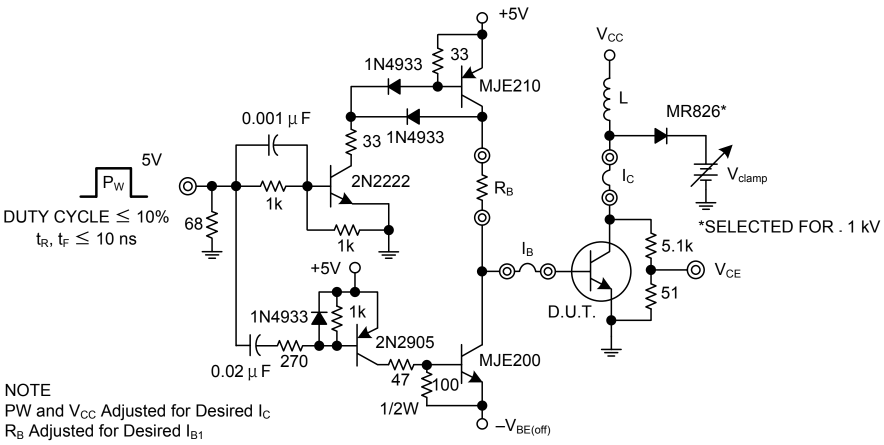
PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
***OFF CHARACTERISTICS**						
Collector- Emitter Sustaining Voltage	V_{CEO}	I_C = 10mA, I_B = 0	400			V
Collector Cutoff Current V_{CBO}=Rated Value	I_{CEV}	$V_{BE(OFF)}$ = 1.5Vdc			1	mA
		$V_{BE(OFF)}$ = 1.5Vdc, T_C = 100°C			5	
Emitter Cutoff Current	I_{EBO}	V_{EB} = 9Vdc, I_C = 0			1	mA
***ON CHARACTERISTICS**						
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, Figure 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

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

■ TABLE 1. TEST CONDITIONS FOR DYNAMIC PERFORMANCE

REVERSE BIAS SAFE OPERATING AREA AND INDUCTIVE SWITCHING

TEST CIRCUITS



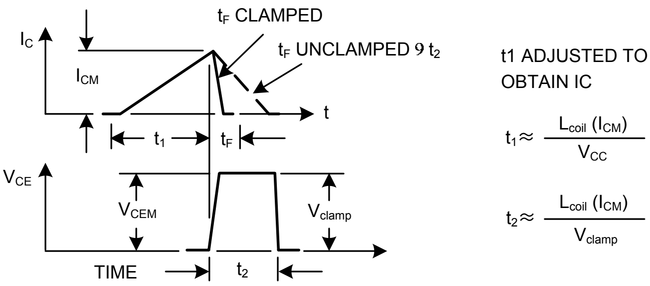
NOTE
PW and V_{CC} Adjusted for Desired I_C
R_B Adjusted for Desired I_{B1}

CIRCUIT VALUES

Coil Data:		
Ferroxcube Core #6656	GAP for 200 μH/20 A	V_{CC} = 20 V
Full Bobbin (~16 Turns) #16	L_{coil} = 200 μH	V_{clamp} = 300 Vdc

TEST WAVEFORMS

OUTPUT WAVEFORMS



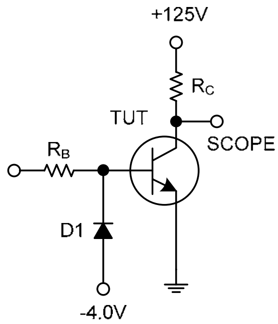
$t_1 \approx \frac{L_{coil}\,(I_{CM})}{V_{CC}}$

$t_2 \approx \frac{L_{coil}\,(I_{CM})}{V_{clamp}}$

Test Equipment
Scope–Tektronics
475 or Equivalent

RESISTIVE SWITCHING

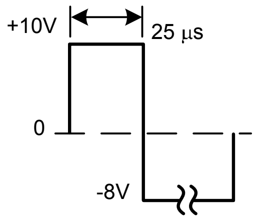
TEST CIRCUITS



CIRCUIT VALUES

V_{CC} = 125 V
R_C = 15 Ω
D1 = 1N5820 or Equiv.
R_B = Ω

TEST WAVEFORMS



t_R, t_F < 10 ns
Duty Cycle = 1.0%
R_B and R_C adjusted
for desired I_B and I_C

■ TABLE 2. APPLICATIONS EXAMPLES OF SWITCHING CIRCUITS

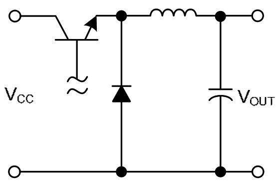
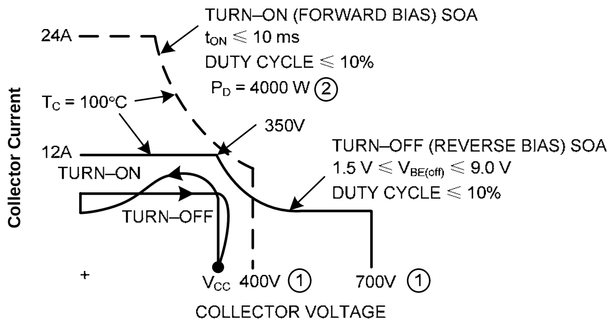
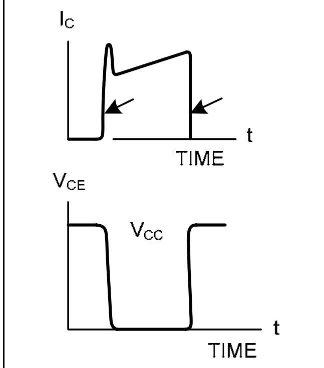
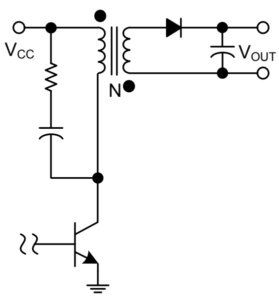
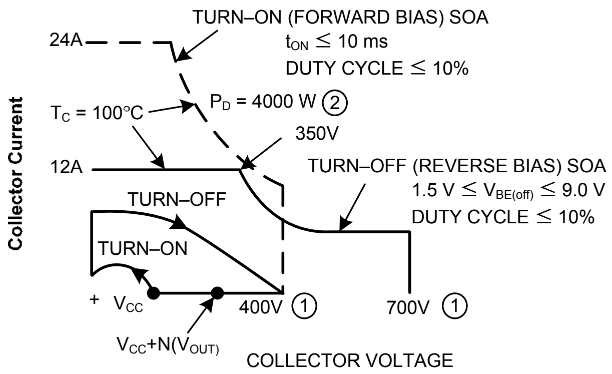
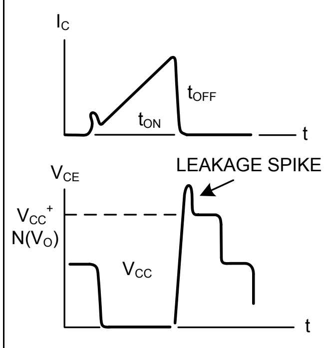
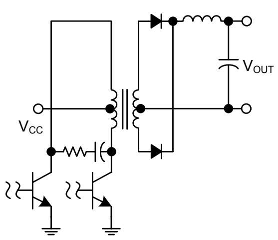
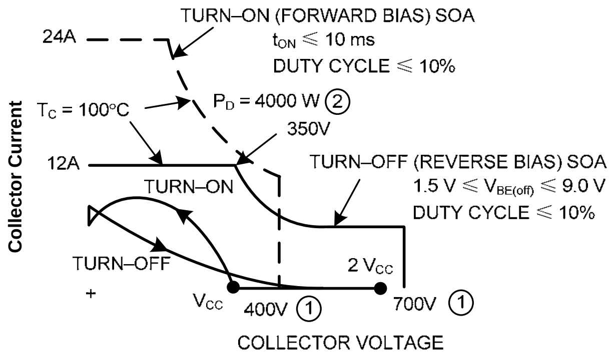
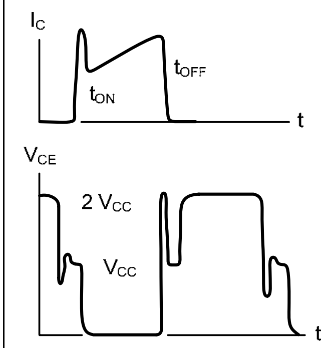
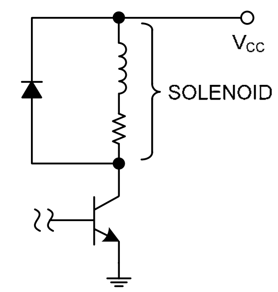
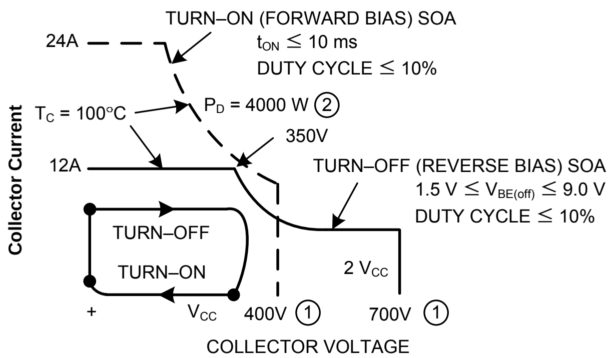
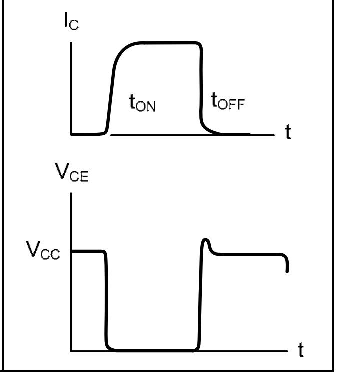
CIRCUIT	LOAD LINE DIAGRAMS	TIME DIAGRAMS
SERIES SWITCHING REGULATOR 		
RINGING CHOKE INVERTER 		
PUSH–PULL INVERTER/CONVERTER 		
SOLENOID DRIVER 		

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	770	100	150	200	240
	100	1000	230	160	200	320
5	25	630	72	26	10	100
	100	820	100	55	30	180
8	25	720	55	27	2	77
	100	920	70	50	8	120
12	25	640	20	17	2	41
	100	800	32	24	4	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 Figure 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 Figure 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

Figure 1. Forward Bias Safe Operating Area

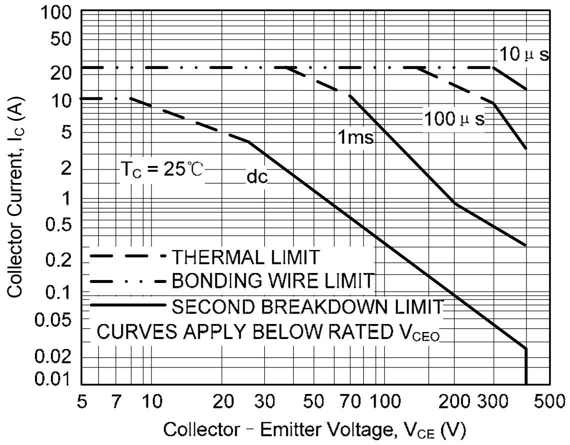


Figure 2. Reverse Bias Switching Safe Operating Area

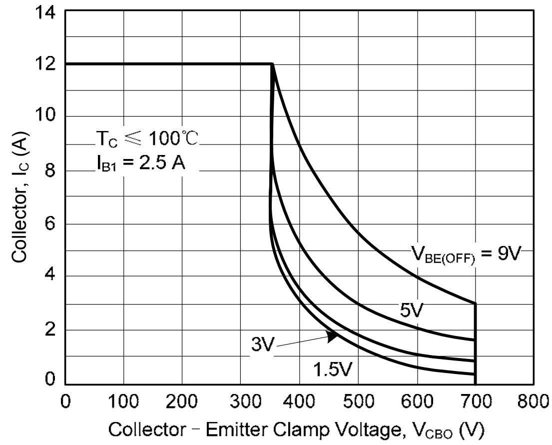
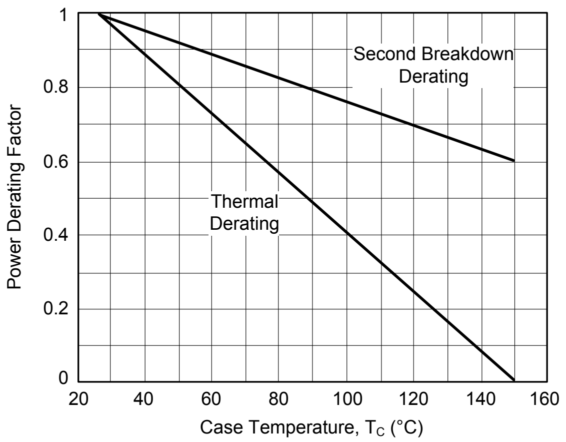


Figure 3. Forward Bias Power Derating

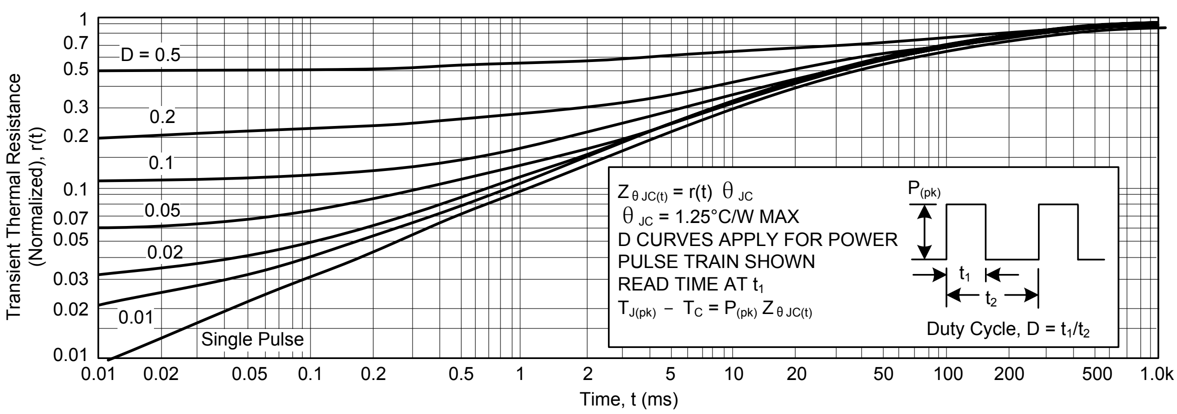


There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation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

The data of Figure 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 Figure 1 may be found at any case temperature by using the appropriate curve on Figure 3.

$T_{J(pk)}$ may be calculated from the data in Figure 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 (Figure 2) is discussed in the applications information section.

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



■ TYPICAL CHARACTERISTICS (Cont.)

Figure 5. DC Current Gain

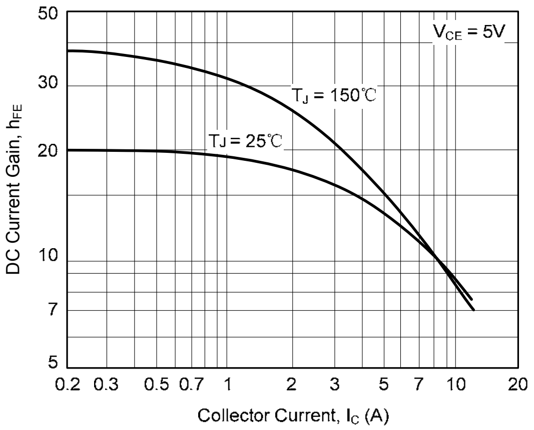


Figure 6. Collector Saturation Region

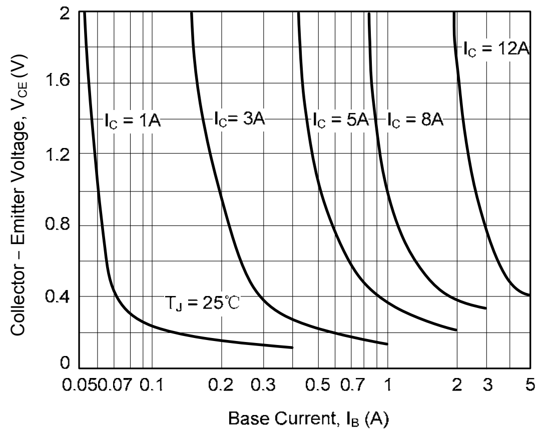


Figure 7. Base－Emitter Saturation Voltage

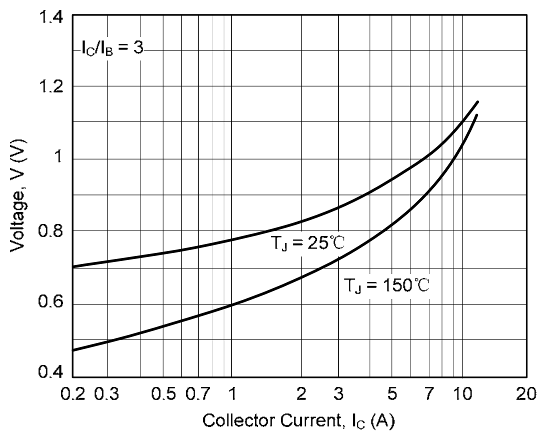


Figure 8. Collector－Emitter Saturation Voltage

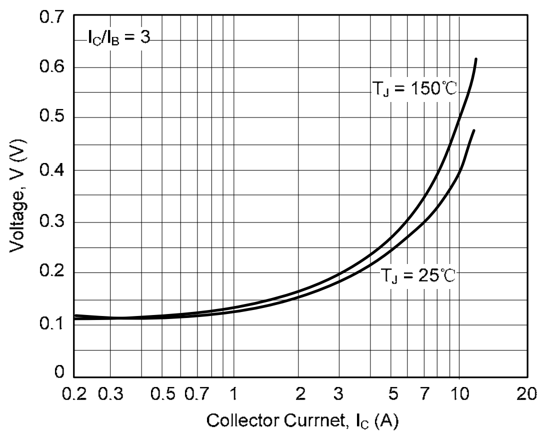


Figure 9. Collector Cutoff Region

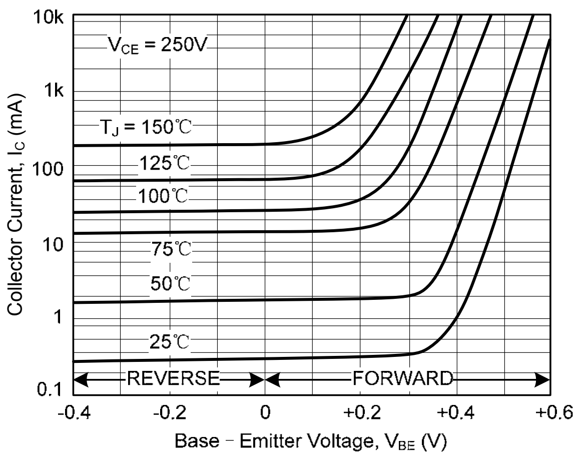
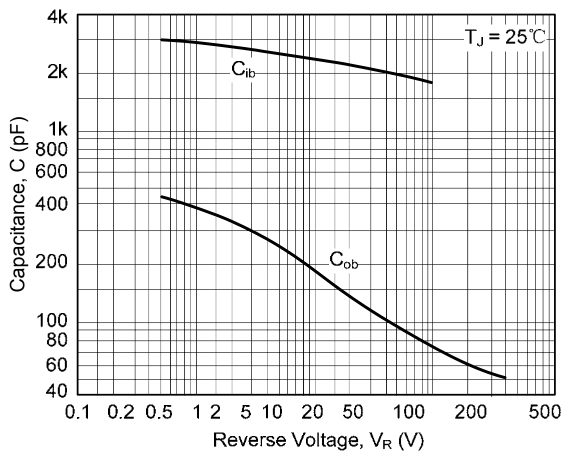


Figure 10. Capacitance



■ RESISTIVE SWITCHING PERFORMANCE

Figure 11. Turn - On Time

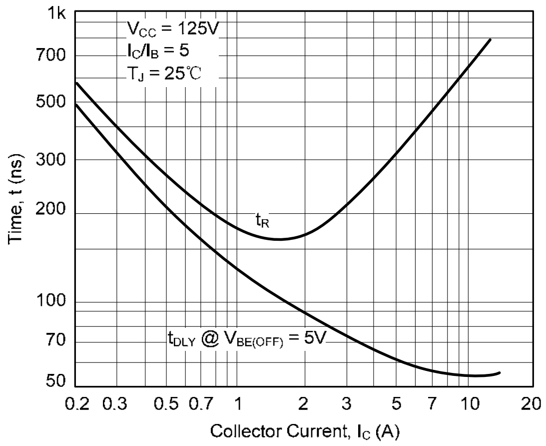


Figure 12. Turn - Off Time

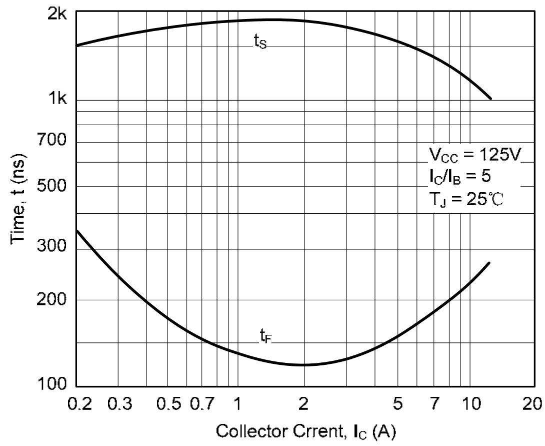


Figure 13. Typical Inductive Switching Waveforms
(at 300V and 12A with I_{B1} = 2.4A and $V_{BE(off)}$ = 5V)